Asian elephants' Social Structure and Mineral Lick Usage in a Malaysian Rainforest using Camera Traps.

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Hii Ning

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Abstract

Elephants (Family Elephantidae) are animals that rely on complex social behavior and organization for survival. The current literature on elephant social organization come from studies in African savannas, an open environment where animals are relatively easy to observe and study. Much less is known, however, about the social behavior of forest elephants, particularly of wild elephants (*Elephas maximus*) in Southeast Asia. Wild elephants in Malaysian rainforests regularly visit mineral licks to supplement their diet with nutrients and to acquire clay to buffer secondary plant compounds This provides a great opportunity to set up camera traps and regularly observe animals that otherwise would be impossible to study in their natural environment. Thus, the objective of this study is 1) to assess the feasibility of using camera traps to study the social structure of elephants in the wild; 2) to describe their social structure; and 3) to quantify wild Asian elephant patterns of mineral lick usage. Individuals were identified using features on the ears, body and tail, or any other prominent profile; and associations between elephants were recorded. Camera traps were set up at Sira Gajah in the Belum Temenggor Forest Complex from October 2012 till October 2013. Video data were retrieved monthly. In total, we recorded 951 hours of videos representing 165 elephant visits. We were able to identify 55 adult individuals while 21 offspring in the age classes of newborn, infants, and juveniles were unidentified over the course of the study. The identified individuals included 26 female adults, 8 female subadults, 15 male adults and 6 male subadults. Seven female family units and four mother-calf units were identified with a median group size of 6 and 2 individuals, respectively. The results show that forest Asian elephants live in smaller groups than their African savanna counterparts. Among the identified elephants, resident family groups were regularly detected, suggesting that mineral licks are important for the feeding ecology of elephants though the reason is still unclear. This study thus provides a baseline of Asian elephant social structure and mineral lick use in Peninsular Malaysia using camera trapping as a recording technique.

Table of Content

1. Introduction

Social structure involves more than two individuals interacting and associating on a spatio-temporal basis (Hinde, 1976; Whitehead & Dufault, 1999). It is a vital part of group living social animals (Wilson, 1975; Whitehead, 1997; Krause and Ruxton, 2002). And it is the essence for understanding and monitoring demographic trends in a population (Whitehead, 1997). Often species that exhibits high levels of social structure also exhibits high levels of cognitive intelligence. Elephants are one such species. The intelligence of elephants is attributed to having one of the largest hippocampuses (Hakeem et al, 2005) and nonsensorimotor cortical neurons (Hart and Hart, 2007) among terrestrial animals. It differs from primate intelligence, which is defined by quick decision making and problem solving. Instead, the elephant's brain structure allows for the capacity to retain long term, extensive information of their environment and social memory (Hart and Hart, 2007). Elephants are *k* specialists and have an abnormally long gestation period with low reproduction rates. They also have one of the longest life spans for terrestrial animals, reaching up to 60 years of age in Asian elephants (IUCN Red List, 2008) and 80 years in African savannah elephants (Moss et al, 2011). This life span makes it difficult to study and conserve the species in a short period of time. Moreover, they are complex in behaviour and can show strong preferences for whom they associate with (Moss, 2001; Archie et al, 2006).

Current knowledge of elephants came from long term researches in the African savanna, where direct observation of savanna elephants (*Loxodonta africana*) are possible. Studies spanning over three decades on elephant social complexity from populations in the Amboselli ecosystem have yielded one of the most comprehensive studies of wild elephants in history (Moss et al, 2011). Collectively, researchers working in similar ecosystems (i.e. semi-arid savannah) have found that savanna elephants associate with close genetic relatives and their dependent offspring (Archie et al, 2011), showing four or more distinctive social tiers and the importance of older matriarchs in their society (Douglas-Hamilton, 1972; Moss and Poole, 1983). The four social tiers are: 1) immediate associations of *mother and calf* units, 2) groups or herds of close genetically related females of mother, sisters and aunts that make up a *family* unit, 3) *bond* groups of distant relatives consisting of multiple families, and 4) *clans*, which encompasses all the bond groups within a common geographical region (Moss et al, 2011). These tiers can be formulated and dissolved within a day or in weeks depending on resource availability. This dynamic is also widely known as the fission-fusion system first described by Kummer (1971) in primates. Elephants are recorded to employ this system by generating small (2 - 3 individuals) to large aggregates (>40 individuals; Moss, 2011) over different seasons,

so as to optimize social interaction when resources are abundant or to avoid conflict with conspecifics when resources are scarce. Sometimes association preferences can be altered permanently, even at the family tier—daughters or aunts break off to form new family units (Archie et al, 2006). The reasons for elephants to live in such changeable societies are knowledge transfer, social learning, and maintaining long term relationships with conspecifics (Aureli et al, 2008, Witemyer and Getz, 2006; de Silva and Wittemyer, 2012). The individual that determines this fission-fusion in savanna elephants is usually the matriarch, the oldest ranking female in the herd (Archie et al, 2005).

A matriarch in the African elephant society determines the fate of the family unit (McComb et al, 2001). Foley (2002) found that mortality rate was higher in herds with younger matriarchs (<35 years old) during an extensive drought period; herds with older matriarch were able to leave the protected areas in Tarangire National Park in Tanzania to find resources, thus having higher chances of survival (Foley et al, 2008). As matriarchs are considered a repository of knowledge of the past and present, they hold vital information of the environment as well as societal complexity (McComb et al, 2001). It is also important for matriarchs to pass on their knowledge to their offspring through social learning (Lee et al, 2011) in the skills required for allocating resources, making decisions and optimising reproduction (Poole and Moss, 2008). This is especially crucial when faced with poor environmental conditions and social disruption (Slotow et al, 2000; Foley, 2002; Bradshaw et al, 2005; Shannon et al, 2013). Most of these examples have detrimental effects that are still being observed decades after the events (Gobush et al, 2009). The recent upsurge of elephant poaching for ivory and the increasing conflict with humans in crop raiding has resulted in a decrease of larger and older individuals from the population (Douglas-Hamilton, 1987; Prins et al, 1994; Wasser et al, 2010; Christy, 2012). The consequences are still unquantifiable as elephants are long living animals (Maisel et al, 2013) and without first understanding elephant social behaviour, researchers would not have recognised the importance of older individuals in defining a successful elephant population.

Whether the social behaviour of African forest elephants (*Loxodonta cyclotis*) is similar to the savanna elephant is still undetermined. In Central Africa, forest elephants are found in much smaller social groups than savanna elephants, of two to three individuals when they visit the forest clearings (Morgan and Lee, 2007; Fishlock et al, 2008, Munshi-South, 2011; Turkalo et al, 2013). It has been hypothesized that lower perception of predatory risks in the forest may be the result for smaller groupings (Laws, 1975; Nyakaana et al, 2001; Moss et al, 2011). Observations of these forest elephants were made possible by elephants visiting ‘bais’, large natural forest clearings in forest ecosystems and the coastal marshes (Turkalo

and Fay, 1995; Morgan and Lee, 2003 & 2007). Although knowledge of these forest elephants had been limited to observations within or near the bais, still, it has provided vital insight into the ecology of the species.

Asian elephants (*Elephas* maximus) on the other hand, have played an essential role throughout human culture and history in Asia (Sukumar, 2003). Studies on the species have been extensive, however, only a handful have addressed their social behaviour in the wild (Vidya and Sukumar, 2005; de Silva et al, 2011a, 2011b; de Silva et al, 2016). This is mainly due to the difficulty and high-risk involved in observing elephants through the thick foliage and the low density of elephants dispersed within the forest (Kumara et al, 2012). Hence, most studies on Asian elephant social structure have been limited to open habitats where direct observation can be repeatedly conducted. So far, we know that social group sizes are variable across different habitats and are also dependent of local climate and resource availability; Asian elephants in Sri Lanka are shown to have relatively smaller foraging group sizes and much more flexible fission-fusion associations between individuals when compared to African savanna elephants (de Silva et al, 2011a, de Silva and Wittemyer, 2012) which could be due to factors such as lack of constraints in environmental resources and the low non-human predatory risk (de Silva et al, 2016).

Peninsular Malaysia is home to an estimated population of 1223-1677 elephants (Saaban et al, 2011) and one of the largest remaining wild elephant populations in South East Asia (Choudhury et al, 2008). Natural history on local elephants have been gathered through opportunistic observations during conflict episodes or translocation activities (Momin Khan, 2014). Indigenous tribes living in the forest also reported elephant and other forest animals regularly visiting mineral licks. Mineral licks are areas of soil deposits or waterholes that contain higher concentration of chemical nutrients than its surrounding area. Studies have shown the importance of geophagy in herbivores, a behaviour of animals consuming soil to either supplement nutrients or counter plant indigestion inhibitors (Villalba & Provenza, 2007). In areas with heavy rainfall, minerals in soil and plants are leached out. This results in low nutrients available for herbivores, therefore mineral licks are sought after to replace lacking nutrients such as sodium, which act as a regulatory function for transmission of nerve impulses as well as gastric acid (Mwangi et al, 2004; Metsio Sienne et al, 2013).

Captive elephants in India observed to deteriorate in health indicated positive recovery after introducing sodium as a diet supplement (Sukumar 1989). Like many other herbivores, elephants rely on these natural resources and frequently visit these mineral hotspots for geophagy purposes (Houston et al,

2001; Holdo et al, 2002; Chandrajith et al, 2009; Metsio Sienne et al, 2013) thus providing a potential opportunity for observation of elephants in high concentration, like those seen in the forest bais in Central Africa (Turkalo and Fay, 1995, Fishlock 2008). However, studies carried out at these mineral lick sites have been limited to species diversity for conservation management and geochemical analysis (Varma et al, 2006; Pollard, 2007; Chandrajith et al, 2009); and there exists a dearth in the literature on elephant social structure in the tropical rainforest.

The data required to study a population's social structure include population size, sex ratio, age structure and distribution of genetic variation (Wilson, 1975). Conventional methods to study elephant population are mainly through dung pile estimation on line transects or opportunistic encounters (Saaban et al, 2008). However, there are limitations in this approach as defecation rates by individuals and groups may differ, thus providing a disadvantage for acquiring individual grouping patterns, sex ratio and age distribution (Lusseau and Newman, 2004). Currently the most effective non-invasive methods to quantify elephant population size are DNA extraction from dung (Vidya & Sukumar, 2005; Janthana et al, 2015) and camera trapping (Kucera and Barrett, 2011; Nichols et al, 2011; O'Connell et al, 2011; Pimm et al, 2015), which is useful for studying species diversity and abundance, occupancy, density and activity patterns (Rovero et al, 2010; Gray et al, 2011; Swann et al, 2011; Ahumauda et al, 2013).

In the dense tropical rainforest where elephants are difficult to observe, camera traps can be utilized to overcome the risk of potential human-elephant confrontation. In addition, animals would be at ease in their natural surroundings without the presence of humans. Furthermore, large scale conversion of forests into cash crop plantations in Malaysia has caused significant decline in elephant ranges, leading to an increase in human and elephant conflict (Momin Khan, 2014). However, we have yet to establish knowledge of elephant social biology and impacts of human-modified landscapes on the biology (Fernando et al, 2006). Other than Varma et al (2006), whose team experimented with camera traps to observe elephants visiting waterholes, as well as elephant "by-catch" footage during species diversity assessments (Maltby 2011; O' Brien and Kinnard, 2011), there have not been any systematic observations conducted for Asian elephants in the forest. With the opportunity of technology available and hotspots with high elephant traffic identified, my study aims to fulfill the following objectives:

1) to assess the feasibility of using camera traps to study the social structure of elephants in the wild;
2) to describe the social structure of wild Asian elephants in Peninsular Malaysia; and
3) to quantify the use patterns of mineral lick by forest elephants.

2 Methodology

2.1 Belum Temenggor Forest Complex

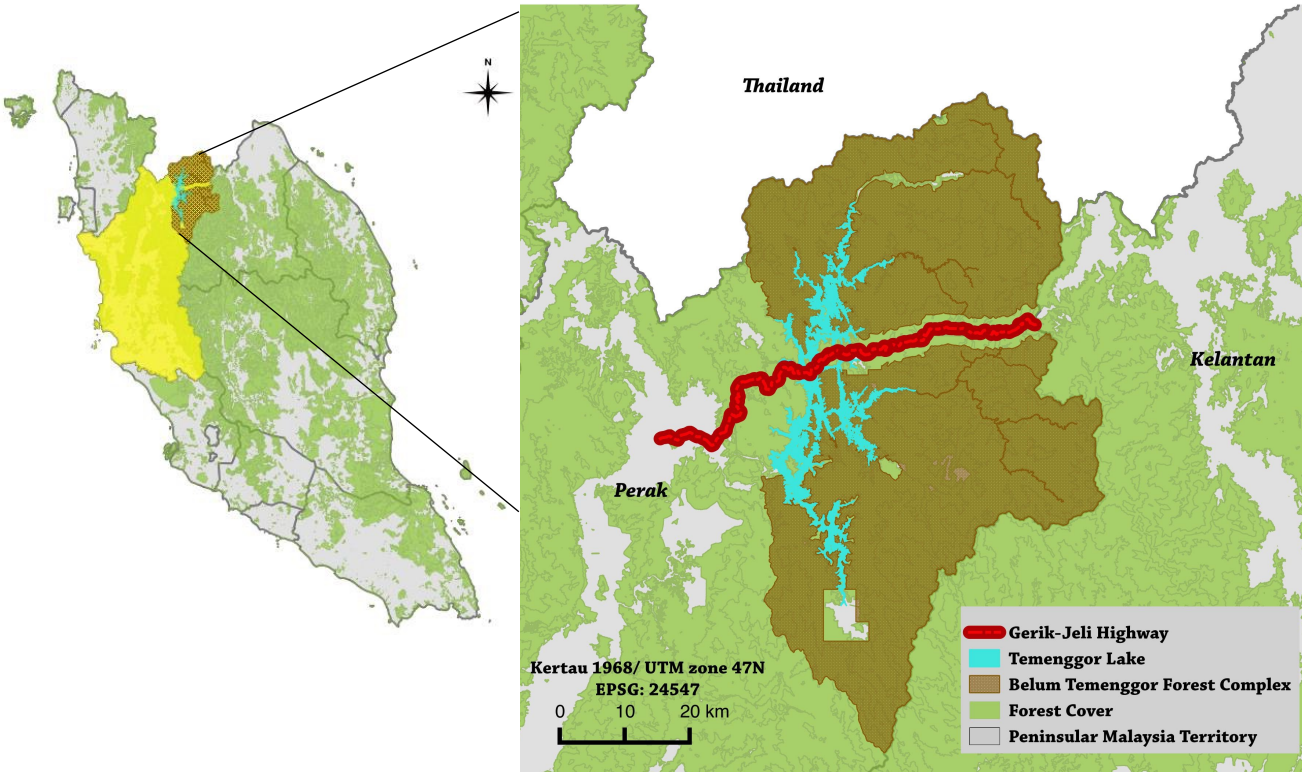

Figure 1. (inset) *Map of Peninsular Malaysia with the state of Perak highlighted in yellow. Belum-Temenggor Forest Complex is situated in the north of Perak, close to the border of Thailand. Sira Gajah is located at the south-west of Temenggor Lake.*

The Belum Temenggor Forest Complex (BTFC; Fig. 1, in brown) is located in the state of Perak, north of Peninsular Malaysia, bordering Kedah in the West, Thailand's Hala-Bala National Park in North, and Kelantan in the East. The forest complex is made up of forest blocks of different managerial statuses with the Temenggor Lake at its heart and the Gerik-Jeli (Fig. 1, in red) highway dissecting the complex. The Royal Belum State Park situated in the north was officially enacted in 2007 under the jurisdiction of the Perak State Park and is protected under state law. On the other hand, Temenggor and Amanjaya Forest Reserve in the south is managed by the State's Forestry Department, which allows logging concessions (MNS & RESCU 2009). Together with smaller blocks like Amanjaya Forest Reserves buffering the Gerik-Jeli highway and Gerik Forest Reserve (not shown on map), BTFC is identified as the Primary Linkage 2 (PL2) in the Central Forest Spine (CFS) Master Plan for Ecological Linkages in 2005- 2011 (NRE). As part of the National Physical Plan (NPP) for Peninsular Malaysia, its purpose was to reduce forest fragmentation

and to link up connectivity between forest blocks—be it protected and non-protected areas—for biodiversity conservation.

The area of BTFC measures approximately 2800km^2 and consists of lowland dipterocarp and montane forest with an altitudinal range of 100–1500m above sea level. Perak is situated inland and is part of the West coast region, where it is less affected by the monsoon season compared to the East coast region. It has an annual precipitation of 2311mm (Wong et al, 2009). Most of the forest was inundated in the late 1970s with the construction of the Temenggor dam for water irrigation, catchment and hydroelectricity, resulting in a 172km^2 man-made lake known as the Temenggor Lake (Yeap et al, 2005). Its rich biodiversity has long been documented by the Malaysian Nature Society (MNS), WWF expeditions and various other universities. These include >3000 species of flowering plants, over 185 species of avifauna—with all 10 species of hornbills found in BTFC alone—and >92 species of fish have been recorded from Sungai Perak alone (Abdullah et al, 2011). The site is classified as Class 1 Tiger conservation landscape of global priority (DWNP, 2008) and is the second largest reserve for wild elephants in Peninsular Malaysia.

The relatively intact ecosystem can be attributed to the communist insurgency that established a base near the border to Thailand during the historical Second Emergency Period from 1968-1989. This deterred external exploitation in the area, leaving most parts of BTFC untarnished as it helped to safeguard biodiversity during peak of development in Peninsular Malaysia (Abdullah et al, 2011). However, this is not the case for all parts of the reserve, as construction and development are becoming an increasing threats to the ecosystem. Despite BTFC's recognition as an important area for protection, the jurisdiction over the different sections of the forest reserve is divided between various agencies and the ongoing threat to the forest complex persists.

2.1.1 Sira Gajah

Sira Gajah (the term *Sira* is the local slang for mineral licks) is located at the Temenggor side of the BTFC. It is known for its frequent usage by Asian elephants and also its ease of accessibility for tourists. It takes approximately 40 minutes by boat from Banding jetty followed by 15 minutes of trekking into the forest (Fig. 1). Obvious signs of elephant dung near licks that had digging activities (Plate 1) indicate that they frequently visit Sira Gajah to consume soil minerals.

The camera traps were deployed in an area of approximately 5km^2 (calculated in Basecamp as a polygon, from the furthest camera trap point to the other) with an elevation of 300m a.s.l. Two licks were selected as sites as they allowed a wider horizon for better image capture. Three entry points were used for acquiring individual identification on age class, height and number of individuals.

Plate 1. *Signs of elephants digging activity as well as elephant dung at Sira Gajah. Over the study period, the area changed significantly due to the frequent visits and digging by the elephant population.*

2.2 Camera Trap Installation

This study was a part of an ongoing camera trapping project to record elephants visiting Sira Gajah since October 2012. Only videos recorded from October 2012 to October 2013 were used for this study. Ten camera traps (Bushnell HD Trophy Cam, model 346788) were set up at strategic locations depending on the terrain. Cameras were deployed based on two criteria: 1) facing mineral licks and 2) trails overlooking access points. These sites also had to have ample light availability. Camera traps were left to record 24 hours daily, and any heat or motion would trigger a 60 second video capture with an interval of one second before the subsequent video recordings (see Appendix 1 for detailed optimal recording camera settings).

Plate 2. *The height of the camera traps was adjusted according to the terrain of the area and distance from tree to targeted spot. If distance between the camera and target area was small, the camera was moved higher while being tilted downwards.*

To capture the essentials of elephant features, the camera traps were installed at approximately 1.5m above ground with the camera tilted downwards (Plate 2). This was to ensure that the video will capture the whole elephant mass when the animal is approximately 5m away from the camera (Bushnell 2011). Camera traps were only mounted on trees with a DBH of more than >10cm because elephants have a curiosity with foreign objects (i.e. camera traps) and have the strength to push over trees that are still young. Memory cards and batteries were refreshed, and broken cameras were replaced every two weeks.

2.3 Video Processing

Upon the first detection of an individual or a group, four types of information were gathered from the videos: i) the start and end time of the *elephant event;* ii) the individuals detected in the event were identified and assigned with an ID, age class, and gender; iii**)** information of associations and group behaviour; iv**)** frequency of the elephant activity at the mineral lick; v**)** tourist and human visitations were documented for activity pattern comparison, the data acquisition was based on the first video detected and the duration spent there.

2.3.1 Elephant Individual Identification

The method of identifying individual Asian elephants was adopted from de Silva (2010) and Williams et al (2013), using ear and body features, as well as tusk and tail arrangements (see Tables 1a and 1b). For Asian elephants, only males have tusks, and females have small 'thushes' that do not grow exponentially like a tusk. Gender was only assigned for offspring younger than subadults when their tusks were visible. Males were sexed based on the presence of tusks or the obvious slouching of the back compared to the squared shaped back of females.

***Table 1a**: Tusk characteristics used in identifying male elephants, adopted from Williams et al (2013).*

Tusk Length	long: double the length from the trunk medium: tusk extending slightly further over the trunk stud: short emerging tusks
Tusk Arrangements	parallel; divergent; convergent; asymmetric
Tusk Thickness	thin tube; massive round
Tusk Angle	straight ahead; intermediate; downward

***Table 1b:** A list of morphological traits used for identifying individual elephants. Images of both ears and the profile of the individual are crucial in identifying the same individual.*

Ears	**Ear Lobes**	**Tail**	**Body Shape & others**
Shape of both ears	Shape of lobes	Length	Shape of backbone
Curls & folds - directions & degree of folds	Length of lobes	Shape	Overall shape
Veins & Wrinkles	<u>Front face</u> Forehead & ears profile	Crooked	Lumps, wounds
Depigmentation		Broken	Habitual behaviours
Cuts, holes, tears, 'finger' notches	Warts, lumps, cuts.	None	thush/tusk

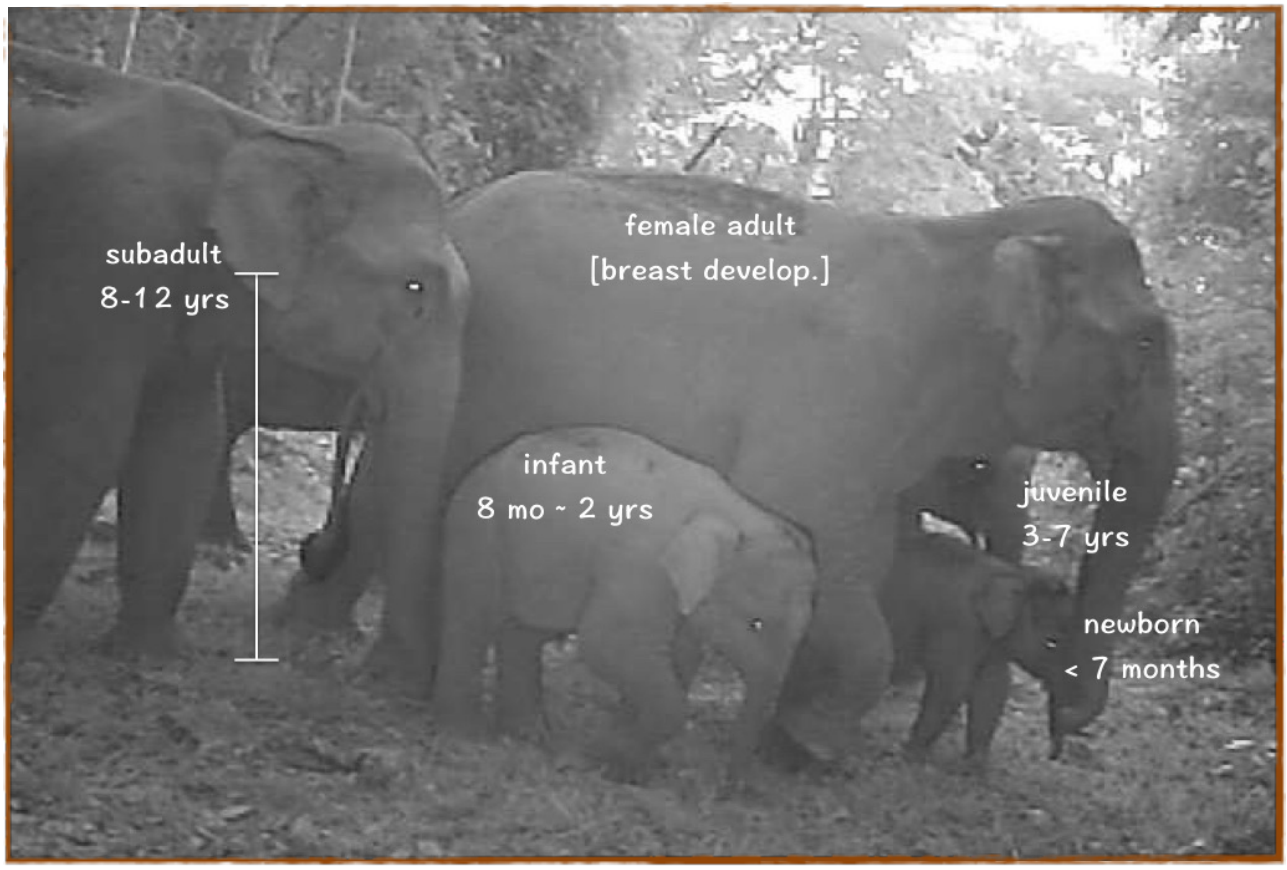

Plate 3*: Age class distribution in relation to female adult's height and size in the group. Method adopted from de Silva et al (2011b). The "newborn" class is assigned to those that are able to pass underneath the female adults belly without difficulty, and are considered to be < 7 months old. "Infant" is defined as an individual, aged between seven months to two years old, and are identified when an individual can stand beneath the chin of a female adult but not able to pass underneath her belly. The age class of three to seven years old are classified as "juvenile and are usually half the height of a female adult, where as "subadults" are between 8-12 years and are those that are shorter than female adult without the development of breasts or are not sexually mature. "Female adults" are those that have breast development.*

2.3.2. Group Information & Activity Patterns

Aperture Version 3.6 (Mac OS) was employed to organise video albums chronologically and to tag videos with elephant ID labels. An ***elephant event*** was defined as a series of continuous triggers by elephants at different camera trap locations. The end of an event was marked when the last triggered video and the next triggered video had a gap of 6 hours, suggesting that the individual or group had left the area. Within each event, there can be multiple groups and individuals occurring at different times with no interactions in between.

Identified elephants were assigned a number ID and names if there were obvious features, they were then organised according to associated individuals of the group in Microsoft Powerpoint with screenshots

from the videos (Appendix 2). Frequency of visits and duration of visits by elephants and humans were recorded in Microsoft Excel. Activity patterns were collated based on the length of duration observed in each event within the 24 hour timeframe, e.g. an event that spans from 11.00pm to 4.00am will give a score in each of the detected hours, then the sum of each hour was calculated and divided by the total of 24 hours.

Since Sira Gajah is a semi-enclosed landscape, it is not possible to consistently determine elephant association in a 500m radius, as specified by de Silva et al (2011b). Instead, I focused on the duration and frequency at which individuals were seen together to describe possible group association. Elephants were categorized as a ***group*** if 1) individuals were recorded at the same time and in the same space and how often they arrive and leave the lick area together, 2) they showed affiliative behaviour such as comforting, interacting, feeding together and or bunching, or 3) the individuals were repeatedly detected in different events associating with the same individuals. Group sizes of different grouping patterns were collated to derive the distributions of group size, sex ratio and median group sizes.

Three camera traps mounted in front of mineral licks allowed the observation of elephant feeding on minerals; I determined whether visiting elephants were consuming soil based on the action of pushing or digging of the exposed soil and using their trunk to acquire broken pieces of rock soil to put into the mouth (Plate 4).

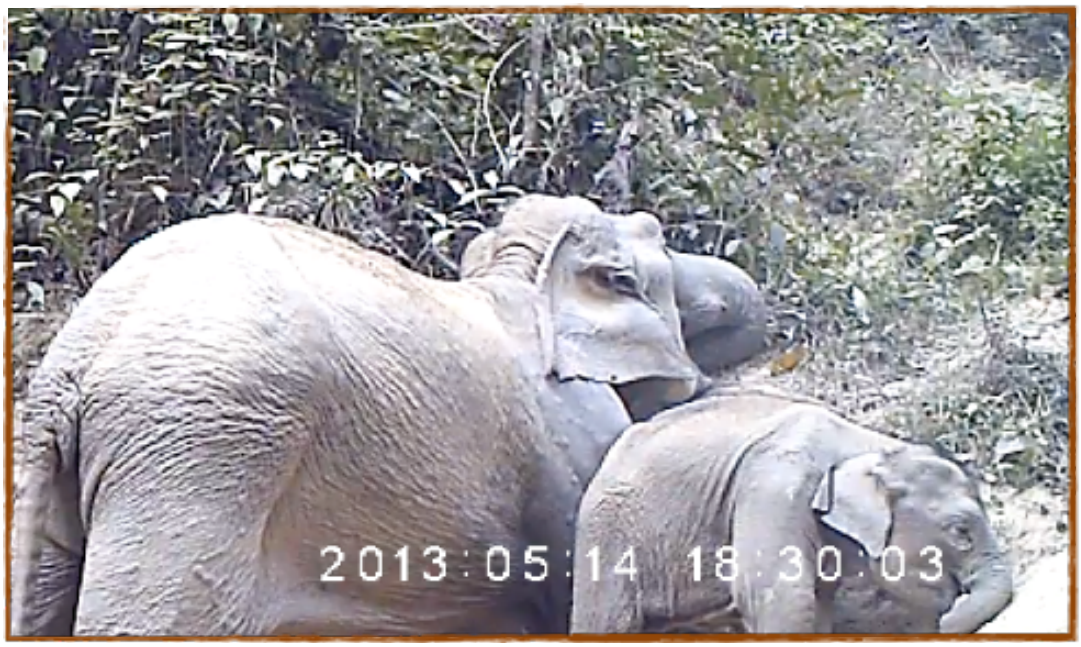

Plate 4: *F10 Pizzarina and her calf 'playing' and feeding at the lick.*

2.4 Data Analysis

Data were analysed using R version 3.1.2 (R Development Core Team, 2014) -- "Pumpkin Helmet". Frequency and duration of visits was calculated based on the ***elephant events*** an individual or a group was detected. Dyadic associations were calculated using the R package 'Asnipe' (Farine, 2013). I used the default setting for *get_network* function in Asnipe which calculates the association rates with Simple Ratio Index (SRI), as detection or observation of all individuals were rarely missed unless unidentifiable. A weighted association matrix was derived from detected events on rows and individual elephants as columns. Only elephants that were detected in two or more events were considered for the association analysis. Group memberships, other than that of descriptive observation, were inferred from the association analysis and visualised- which will show in a form of polygon- using the R package 'Igraph'. Since the study period was short, processed data was insufficient to infer social units. However, a Mantel test was used to test the strength of group definition I assigned based on individual's detection rates. Visiting frequency was tested for correlation with rainfall over the study period.

3. Results

3.1 Identified individuals and Grouping Patterns

I recorded 165 elephant visiting events, 43 of which were discarded due to poor quality, with only a remainder of 122 usable events (these events were based on the 6 hour intervals and included all groups that visited in the same time frame as one event). Seventy-six individual elephants were identified. Figure 2 shows the distribution of age and sex class in the identified elephants detected on the camera traps, with 26 female adults, 8 female subadults, 15 male adults, 6 male subadults and 21 offspring comprising the three age classes of juveniles, infants and newborns. The three offspring categories were combined into one for this study as there was difficulty in accurately determining their height. The sex ratio of male to female adults was 0.57: 1. Table 2 shows the individuals identified with name codes, age classes and family memberships. Among the detected events, three types of groups were observed, namely female groups, odd groups and lone males.

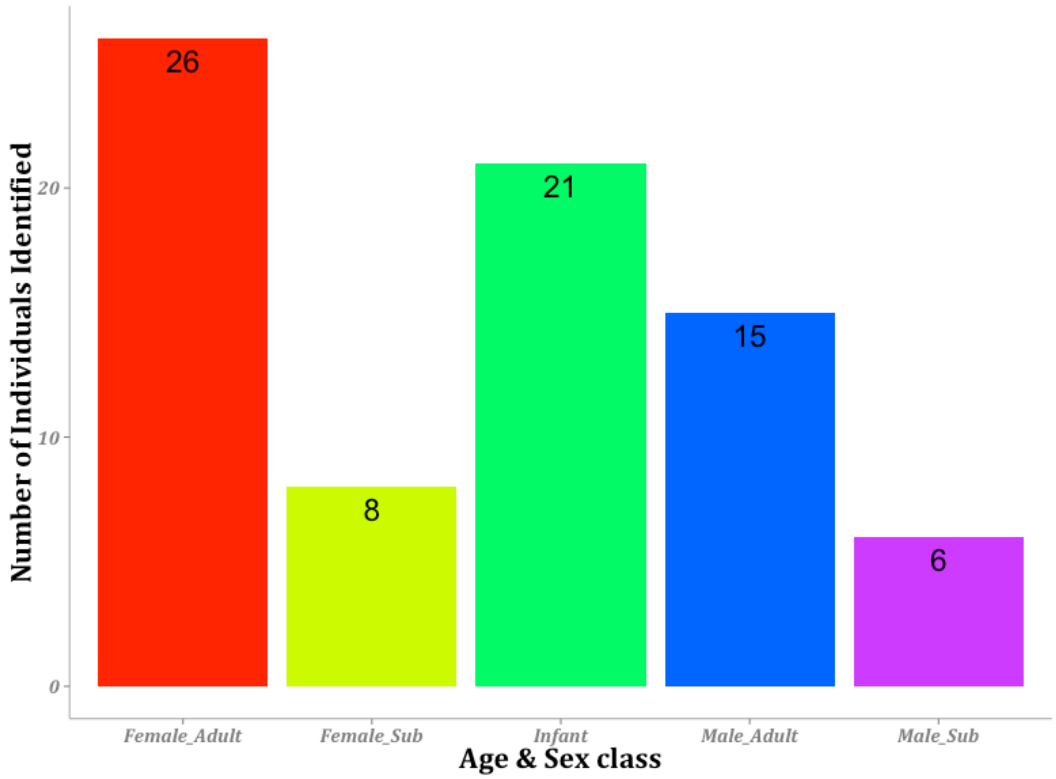

Figure 2*: Distribution of age class and gender in the identified elephants. Calf age classes of 'Newborn', 'Infant', and 'Juvenile' were collated into the 'Infant' category for ease of reading, this category is aged but not identified.*

Table 2: *Identified individuals in arrangement of three groups (see Appendix 2 for imaged ID details). Name coding: F= female adults, S=subadult, M=males. Offspring were not identified. Table 2a (top) and 2b (middle) are female groups, with the only observable difference in their group size preference. Ungrouped individuals had no obvious association with any groups and were occasionally caught on camera. Males in Table 2c (bottom) were observed to visit the mineral lick alone or in a group of two males, while occasionally joining female herds at the lick.*

Family ID	Female Adults	Subadults	Offsprings	Total
H1	F01-09 Rapunzel F07 Notetail F08 Lady Boss	S05 Subby S06 Tinkerbell	2	7
H2	F10 Pizzarina F12 Lumpy F13 Thundress	S37 Whiskerless	2	6
H3	F14 Cauliflower F15 Box Ear	S36 M05	2	6
H4	F20-24 Judi D F21 F22 HafSca2	M06 Macho/ M18 Ba (inconsistent)	2	6-7
H5	F31 Righty-O F32	-	2	4
H6	F30 Sahara F34 Left C F35 Wanda	M22 S41	5	10
H7	F18-23 Big C F19 Aly F27	-	2	5

Odd groups ID	Female Adults	Subadults	Offsprings	Total
Tailess	F11 HafSca	M01 Tailess	-	2
Short T	F28	-	1	2
Hook T	F29	M03	-	2
25 Trio	F25	S38 Lopez	1	3
ungrouped/ individuals	F04-16 Left Blindy F44 F45	S39 S42 Betty	2	7

Males (15 individuals)		
M02 B.O.	M10	M15 Sawtooth
M04 Pedro	M11-17 Right-Notched	M16 Mike-C
M07	M12 Curdy	M19
M08 Huat	M13 Baldy	M20 Left-Chunkie
M09 Fourked	M14 Pendek V	M21

As seen in Tables 2a and 2b, seven female herds and four odd groups were identified. This was based on the observation that groups with more than three individuals were considered as 'family groups'; where as 'odd' groups were those seen in smaller family groupings, i.e. at least one breeding female and her calf, with 2–3 individuals only. The most commonly recorded group size was a median of 6 individuals with a range of 2–10 members in a group (Table 3). Structure of the groups observed ranged between 2–3 female adults, 1 subadult and 2 offspring (Figure 3); with the exception of the odd pair. They were consistently observed together over the study period except for the group #H5, which was only detected once (Figure 5).

Table 3: *Group structure and group size (mean and median) observed among the two female group types.*

Age Classes	**All** **n=11**	**Family Groups** **n=7**	**Odd Groups** **n= 4**
Female Adults	2 ± 0.89 SD	2.57 ± 0.5 SD	1 ± 0 SD
Subadults	1.09 ± 0.7 SD	1.28 ± 0.75 SD	0.75 ± 0.5 SD
Juveniles	1 ± 0.89 SD	1.4 ± 0.78 SD	0.25 ± 0.5 SD
Infants	0. 8 ± 0.98 SD	1.1 ± 1.06 SD	0.25 ± 0.5 SD
Mean Group Size ± SD	4.89 ± 3.5 SD	6.35 ± 3.09 SD	2.25 ± 1.5 SD
Female Adults	2	3	1
Subadults	1	1	1
Juveniles	1	2	0
Infants	1	1	0
Median Group Size (range of individuals)	6 (range 2-10)	6 (range 4-10)	2 (range 2-3)

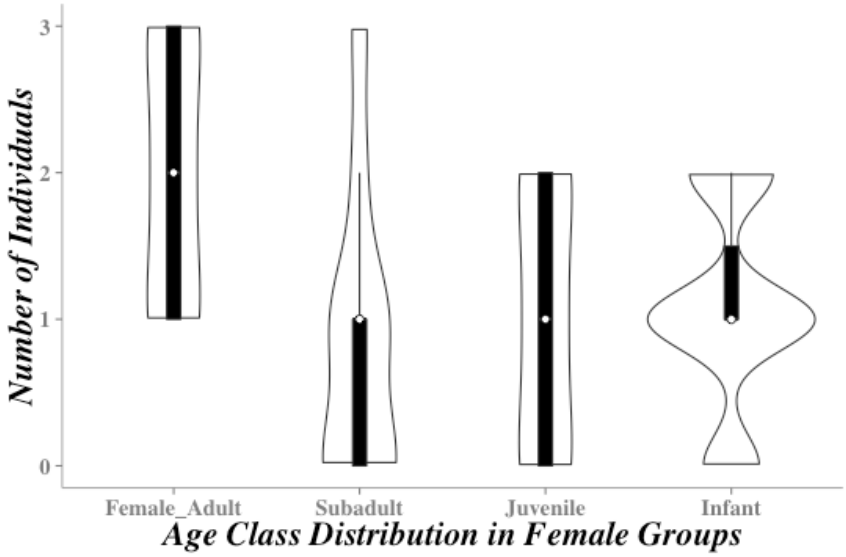

Figure 3: (left) *Violin with nested boxplot of the distribution of age class within the family group and odd pair categories. The white dot shows the median of the age class category.*

On average, the group size observed in all the female groups, which includes both family and odd groups, was 4.9 ± 2.9 individuals. However the group size of female herds averaged 6.4 ± 2.4 individuals; while the average of odd groups were 2.3 ± 1.07 individuals (Table 3). The distribution of age classes within the female groups varied between the different types of groups as described in Table 3. Figure 3 shows the age class distribution of female groups of all types (family and odd groups).

In total, four male subadults (**M01** attached to F11 as Tailless Duo, **M03** with Hook T Duo, **M05** belonging to H03 and **M22** to H06) were still observed to be with the female family and smaller odd groups, suggesting they have not detached from their natal groups at this age category. Two male subadults (**M06** and **M18**) seemed to appear when family group #H04 arrived at the study site though the two males were rarely seen within a short distance of the herd and tended to arrive earlier or leave later than the main herd members.

3.2 Social Network Analysis

All identified elephants had shown interactions, except for M16 (code: B7 in fig 4). There are two parts of group membership shown in figure 4, coloured nodes are those assigned through my observation and the nodes represented in the six highlighted polygon colours are those inferred through the network analysis. The Mantel *r* statistics of 0.1104 indicates that there is a correlation between the group assignment which was allocated manually and the weighted adjacency matrix calculated using the asnipe package. The p-value of 0.008 indicates that the results are statistically significant (alpha <0.05). The Mantel test indicates that the group membership that was assigned manually based on the social preferences observed positively correlates with the adjacency matrix group attribute (r: 0.1104, Significance result: 0.008).

Dyadic association rates was highest within groups with the value of >0.5 weighted network (Appendix 3: Association matrix). Subadult males M08 and M16 of group H4 showed weaker association weight of 0.4. Odd groups show mild association with other family groups of approximately 0.1 weigh only. Interestingly, F45 a newly identified female, had close to 0.5 association weight with H6's F18-23 and F19. Male association rate between groups and odd pairs were lower than 0.1 with the exception of M13 who has 0.2 association rates with the F25 odd pairs.

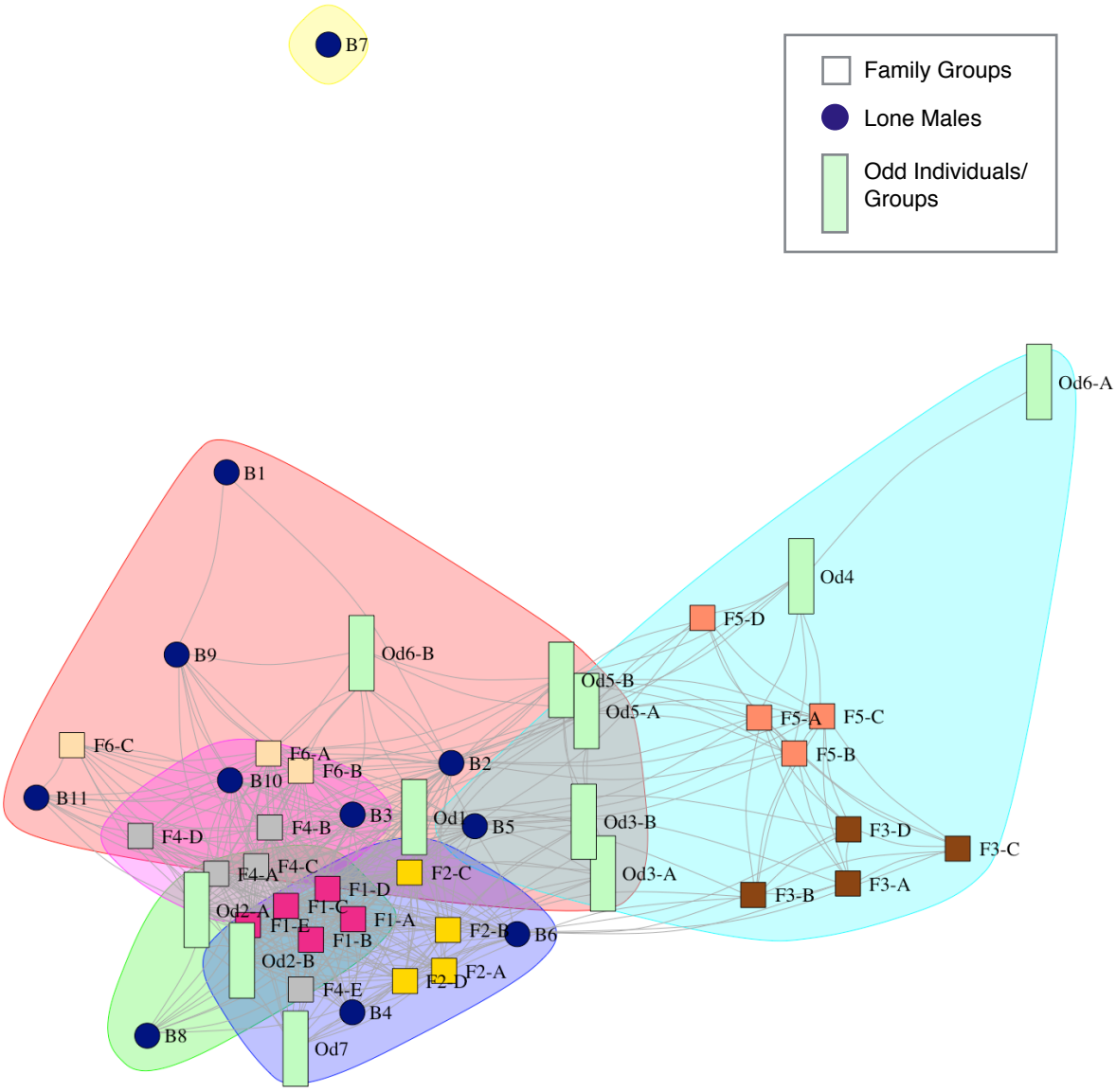

Figure 4*: Network association diagram showing individual associations of the study group. The nodes are assigned with name codes for individual elephant identified, and the edges represent the probability of an individual being detected with another individual. The different shape of nodes shows three types of social groups: female groups (square, coloured by group identity), odd pairs (rectangle, light green) and male loners (circle, dark blue). The colours for family groups were assigned through direct observation. The highlighted polygon represents the clusters detected, which are formed from the edges with higher proportion of weight within communities or clusters, also called social groups/units.*

3.3 Frequency of Visits and Mineral Usage by Elephants

Seven family groups visited the mineral lick with an average frequency of 14.14 times (± 12.6 SD), with a range of 1–33 visits (Fig. 6). Herds H4 and H1 made the most visits to Sira Gajah during the study period with 33 and 30 visits respectively. On average the herds revisited the mineral lick at 10–12 days intervals. Five odd groups, including F04-16 Left Blindy, the individual whom was seen alone on most visits, visited

the mineral licks with a frequency of 9.2 (± 3.9 SD), ranging between 5–15 visits. Among these groupings, 25 Trio and Tailess Duo visited the lick 15 and 11 times respectively. The 18 lone males recorded visited the mineral lick at a frequency of 4.6 (± 3.03 SD), with a range of 1–11 visits. In contrast to other males, M04 visited the lick the most with 11 counts, followed by M12 and M17 with 9 visits (Fig. 6). Figure 5 below shows the correlation with visitation pattern and rainfall within the vicinity of the study site.

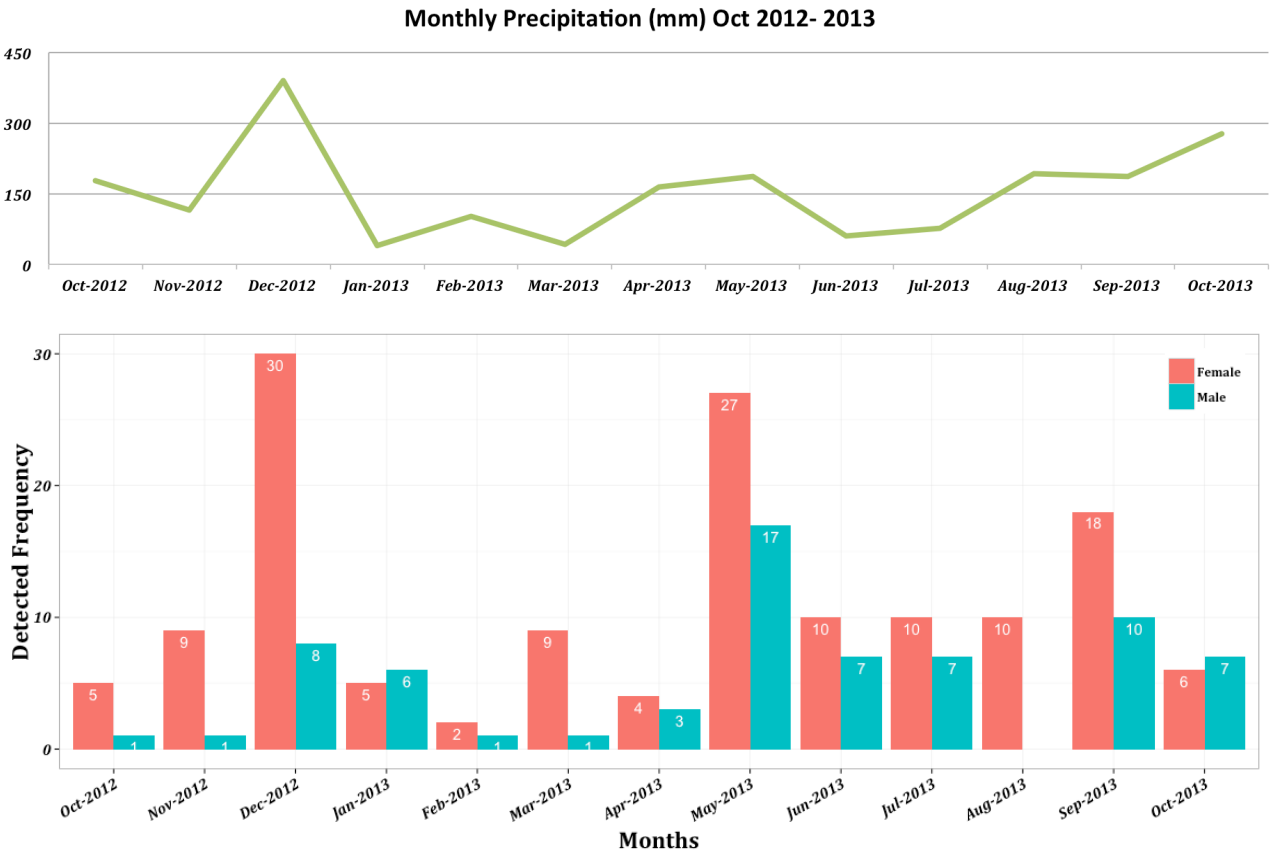

Figure 5 (above): Precipitation rates over the study period and the frequency of visits female groups and male. Meteorological data acquired from the Ayer Banun station located near the Banding jetty lake (Malaysian Meteorological Department, 2015). (Below) Female and male elephant visitation pattern throughout the study period. December 2012 and May 2013 showed the highest frequency. Relationship between rainfall and elephant visiting rate showed a Pearson's correlation of 0.5, however the p-value was 0.08, suggesting a marginal significance of the correlation.

Figure 7 shows the monthly visitation patterns of all the female groups and male elephants that visited the most often. The month of May 2013 had the highest rates of elephant visits amounting to approximately 24% of the total visits in 2013. This was followed by 14% of visits in December 2012 and 10% in September 2013. February 2013 had only 2 visits (0.9%) from H5 and M07. There was low detection in October 2012 (2.6%) because the study started in the middle of the month.

The time spent at the study site by visiting populations ranged between 0–1398 minutes [23.3 hours]. On average, they spent 289 minutes (approx. 4.5 hours) at the mineral lick area. Female herds spent 348 ± 292.4 minutes (n=101) as compared to males with 293.2 ± 260.3 minutes (n= 83). Odd groups (n=51) spent 302 ± 331 minutes at the licks.

Among the female groups (Fig. 8a), herd H7 had the highest mean duration spent at the lick: throughout their 11 visits to the site, they spent an average of 6.7 ± 4.1 hours, with a range between one minute and 14 hours. Herd H1 spent 6.3 ± 5.4 hours, ranging between one minute and 19.81 hours; H4 with a mean duration of 5.96 ± 5.2 hours, with a range of 1 minute to 18 hours. Left Blindy floater on average spendt 5.9 ± 3.8 hours at the lick, ranging between 1–11.5 hours.

In Figure 8b, males that showed a pattern of less frequent visits tended to spent a longer duration at the lick area. Individuals M11 and M13 seemed to display such behaviour. On average M11 spent 7.8 ± 5.2 hours with a range of 0.3–11 hours while M13 spent 9.3 ± 3.5 hours with a range of 4–13 hours). Individual M04 had the highest visiting rate but spent on average 4.2 ± 5.5 hours with a range of one minute to 17 hours.

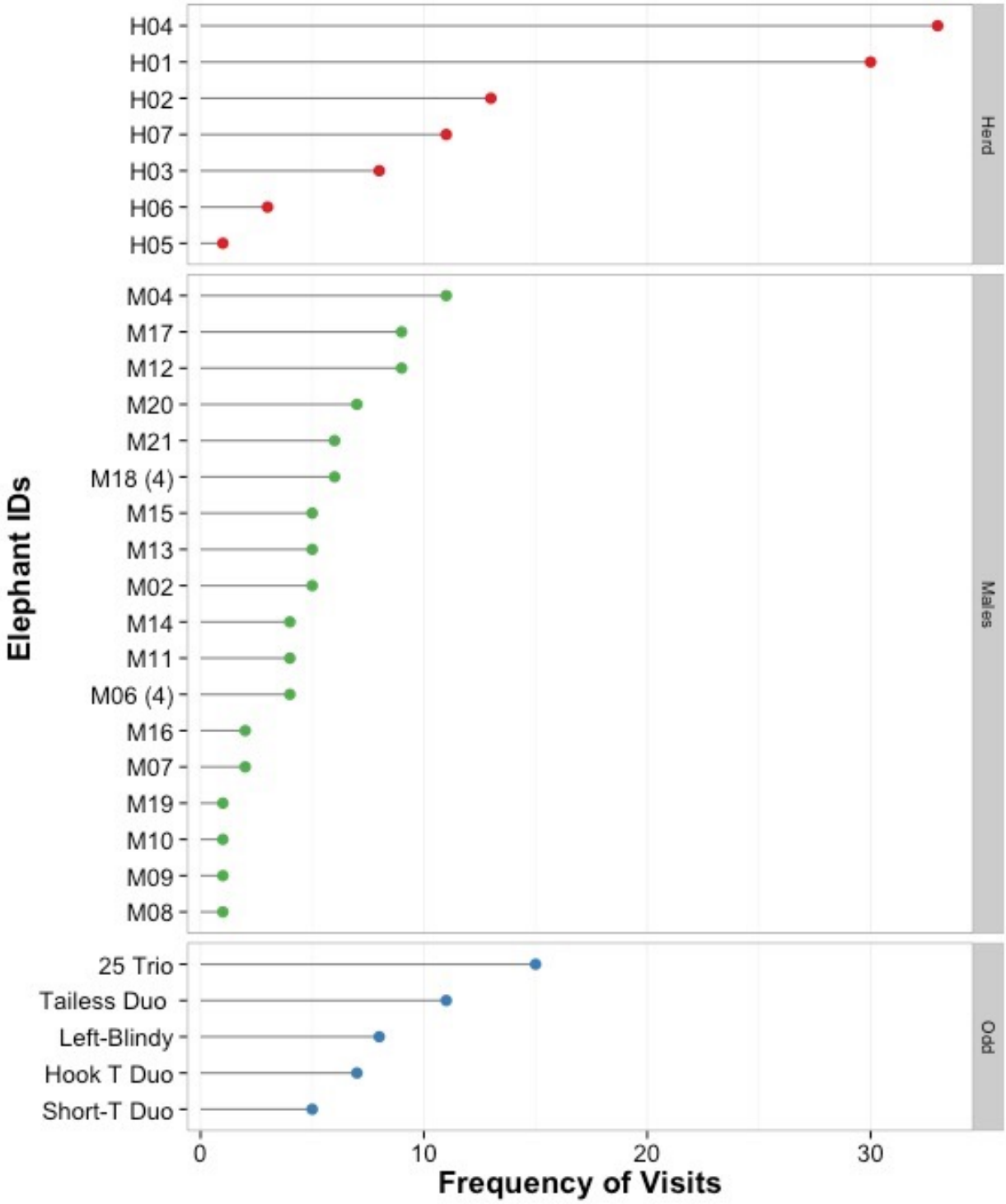

***Figure 6**: Cleveland dot plot showing the distribution of visiting frequencies categorized by female herds, individual males and odd female groups.*

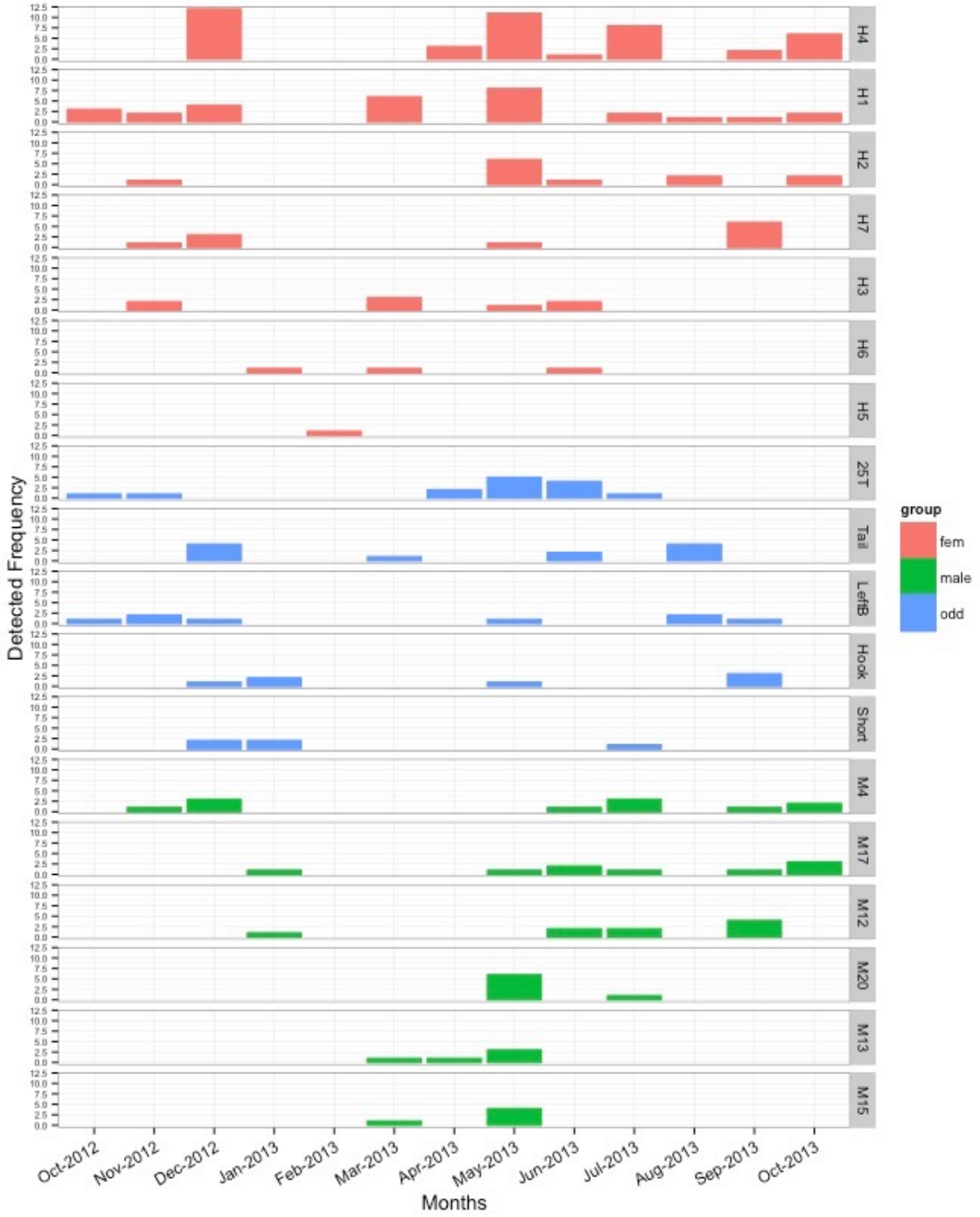

Figure 7*: Visitation rates visualised in months by elephant groups over the study period, sorted from highest to lowest visitation rates between the three group categories.*

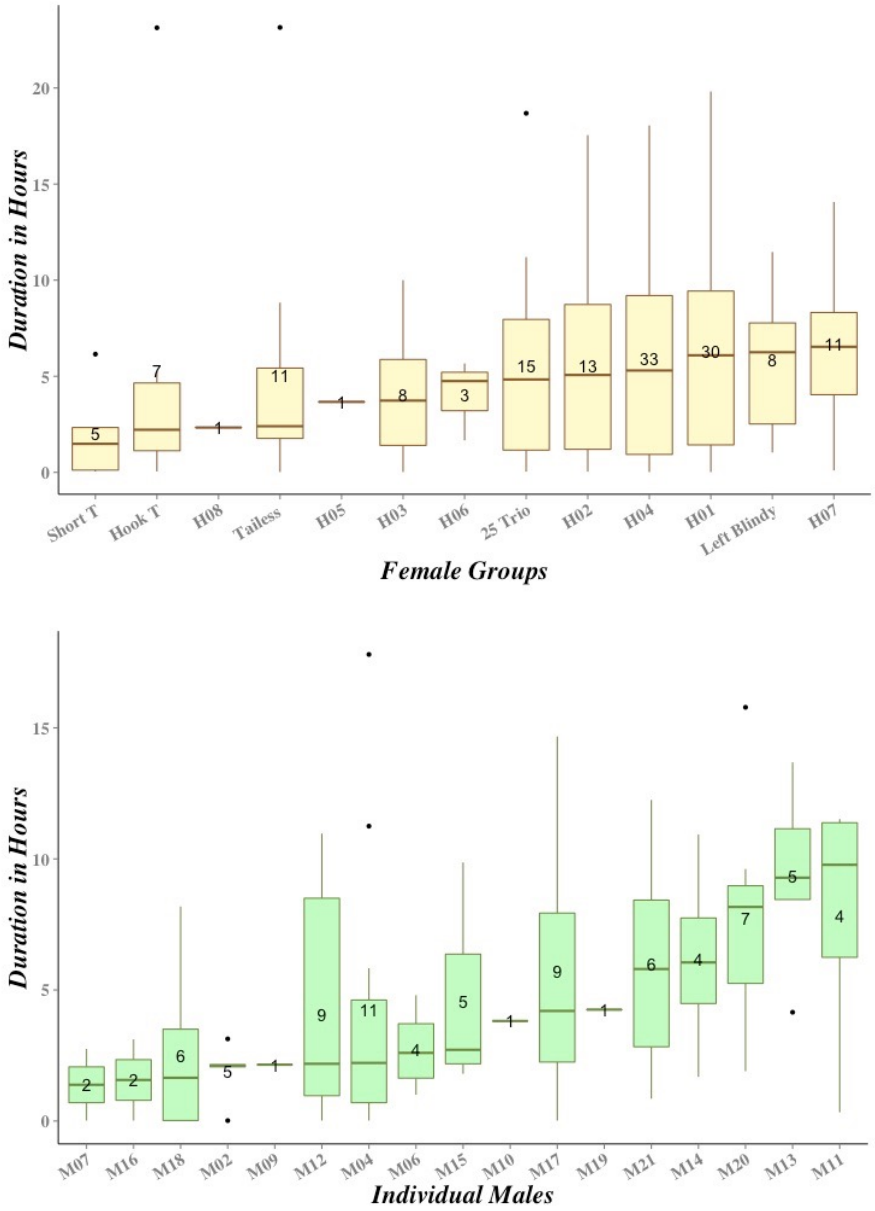

Figure 8. *[a Top] Box and Whisker plot of female herds, odd groups and [b, Bottom] individual males' visiting duration, ordered by median. The wider spread of the standard error bars indicated a higher number of detection leading to higher variation in duration spent there by the individual or groups of elephants.*

3.4 Activity patterns of Elephants and Humans

Elephants displayed a clear nocturnal activity pattern at the mineral lick as shown in Figure 8, with 71% of the activity occurring between 2000 and 0600 hours. Activities commenced at 1700 hours and peaked at midnight, subsiding after 0800 hours. As captured on the camera trap time stamps, human visits were between 0900 and 1300 hours with the 1000 hours (14%) and 1100 hours (42%) being the most active hours.

Among all the elephant events detected, there was a significant difference in soil use and consumption activity carried out between males and females. Female visits had a higher record of individuals feeding in front of the lick camera traps, whereas male elephants fed significantly less in front the camera traps. Only 11 male elephants detected in 19 events were seen to be consuming minerals (Fig. 9). Individual M21 was found to feed at the lick in three out of the six events he visited. The actual time the elephants spent feeding on minerals was not quantified in this study.

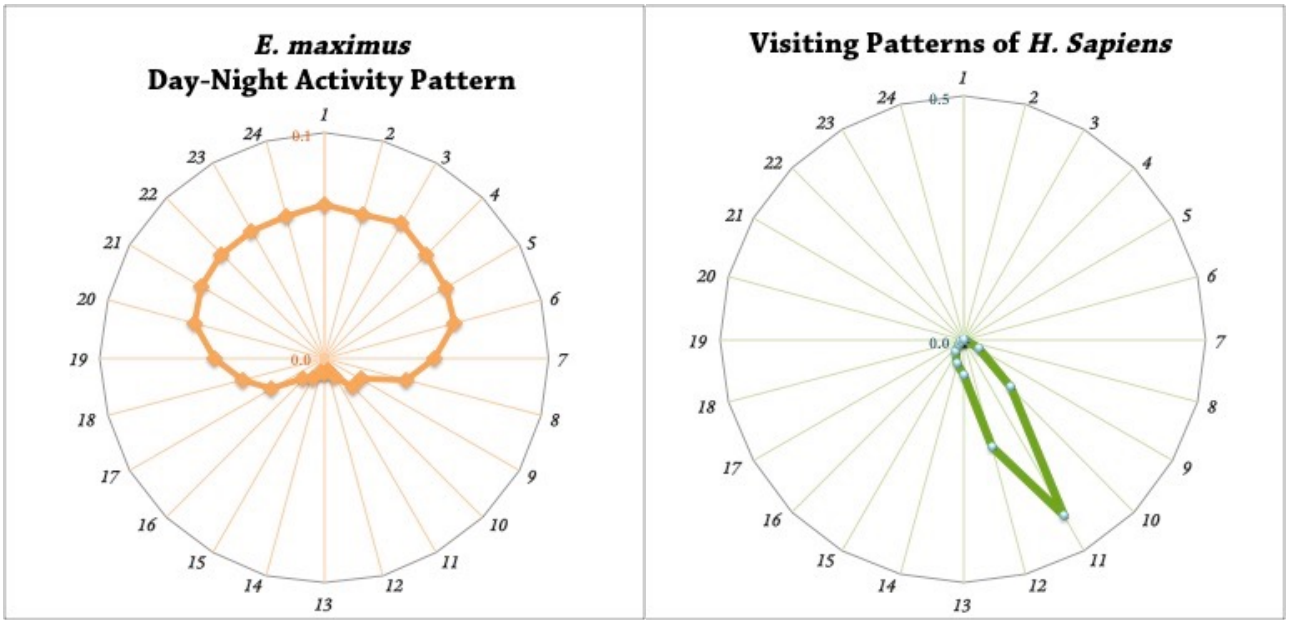

Figure 9. *[Radar plot showing the visiting intensity to the mineral lick on a daily basis. b) Visiting patterns of humans (tourists and MEME staff) extracted from the triggered videos.*

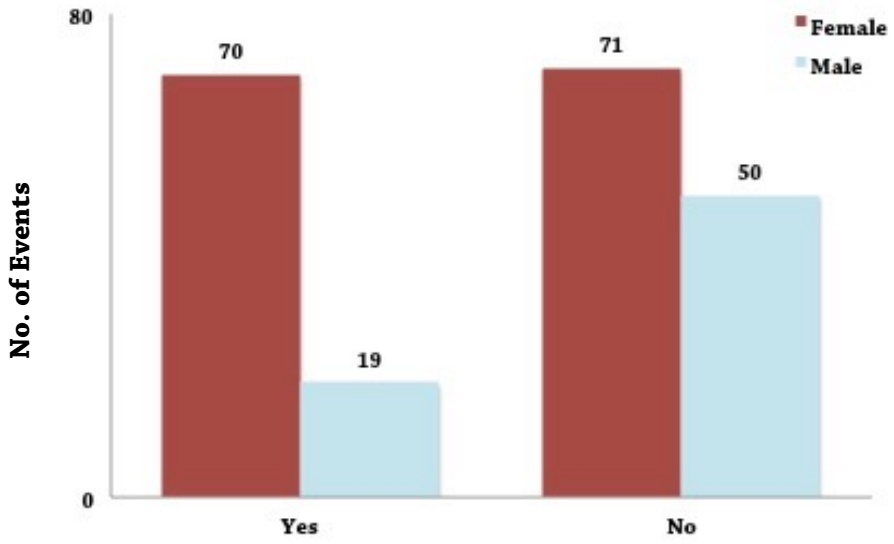

Figure 10. *Barplot showing count data on mineral lick consumption in gender. There was a significant difference in feeding activity between females and males (X= 0.002, Chisquare), with females consuming mineral more often than males.*

4. Discussion

4.1 Using Camera Traps to Study Elephants

This study has shown that camera traps are a feasible approach for observing Asian elephants in the tropical rainforests (Varma et al, 2006; Head et al, 2013; Gessner et al 2014). The distance from trail or lick and light penetration in the micro-habitat appeared to be an essential factor for acquiring quality images with fine details on the ears. Camera trapping elephants requires flexibility as the surrounding interacts with their body mass in a way that requires a lot of trial and error in judging potential micro-habitat. For example, the enclosed sites of mineral digging pits and camera position rarely allows macro-information of elephants, i.e. facial features from the front view and overall body shape; whereas open areas with cameras overlooking paths lack in providing a close-up view of their ear characteristics. In this study, cameras were mounted at a tree height of 1.5m and above while the distance from camera to focal point at least 6m can be fixed as the baseline for camera trapping elephants. The downward tilt allows for better coverage of smaller offspring that would otherwise be overlooked, thus collecting data that is important for informing the social structure in a population study.

With the transition in light availability between day and night, the camera traps commence infrared filming from 6 to 7pm and 7 to 8am in most of the recordings. As shown in Plate 5, together with natural day light and infrared light the images tend to be overexposed and most of these videos were difficult to use for data analysis. In terms of exposure, this could be a camera brand disadvantage posed by the model Bushnell as compared to other brands of camera traps like Reconynx or Cuddeback found by fellow camera trapper working in the same environment (Moore, J, pers. comms.). Moreover, underexposure in the night also yielded unreliable images and were thus omitted from the identification process. Thus far, I have not found a better way to tackle these transition issues. Despite the fact, many direct observation studies have had similar light exposure issues (de Silva, 2010; Fishlock, 2011; Turkalo et al, 2013) but this not considered to be a crippling factor.

Lastly, infrared images of elephants which appeared wet during raining events were rarely usable. This was because the reflection of the infrared light caused image distortion, especially at the ear features where the ear folds cast more shade on dry parts which were less reflective. Thus, images of new individuals or groups detected during raining events were used conservatively.

Plate 5. *Overexposure of light during dawn and dusk had an impact on the quality of the identification.*

4.2 Individual Identification

The features for identifying individuals adopted from de Silva (2010), Williams et al (2013) and Arivazhagan & Sukumar (2008) were likewise found to be important in this study, though slight adjustments in the identification are needed for the videos recorded. Other than the conventional characteristics reliably used in identification (Goswami et al, 2011), tail shape was found to be the most useful characteristic in the initial differentiation of individuals (Vidya et al, 2014), especially during situations where many individuals were captured but only parts of them visible.

In this study, backbone shape was the least useful feature for identification because visiting elephants did not seem to have distinct concave or slouching backs visible in the videos as compared to those of direct observations in Sri Lanka (Fernando et al, 2009). Other than that, most of the time, the terrain where the camera was set up did not allow clear visualization of the back shape. In summary, together with other features described in Table 1, ears, tails, and other bumps and lumps were the most useful for identification on camera trap footage [see Appendix 2 for individual ID].

The 43 events discarded consisted of both female and male detections. Most of these events were triggered at night and at a distance from the camera, where the infrared light could not be reached. The images were too pixelated for accurate identification to be carried out. In future studies, I would recommend others to improve identification skills with direct observation of animals, either with wild or captive specimens to increase capability in differentiating changes in features during elephant movement. Learning to identify elephants is a long process which requires trial and error enforced with direct

observatory training on wild or captive elephants. Consequently this study was carried out over two years but the confidence in differentiating the known elephants was strengthened with the reoccurrence of individuals.

4.3 Elephant Social Structure

4.3.1 Female Group Associations

Results from the present study showed that elephants in Peninsular Malaysia display grouping patterns similar to family social structures observed in other studies. The main social group consists of more than six individuals in mainly matrilineal groups while the smaller social pairs of mother and calf units, together with a few floaters (Fernando and Lande, 2000; Sukumar 2003; de Silva et al, 2011a). The number of available females in the family are found to be similar to de Silva and Wittemyer (2012), with three in each herd and most of the individuals having some form of breast development, indicating frequent lactation. This, not only indicates that the tropical forest elephants have similar social composition to the Sri Lankan and Indian Asian elephants, it also suggests that regular breeding occurs in the visiting population. However, the 1:1 mother to calf ratio in the study population suggests a longer inter-calving period as compared to the general knowledge of four years between inter-births in other Asian elephant population (Williams et al, 2007). Wittemyer et al (2013) put forward that these elongated inter-calving intervals could be an effect of ecological conditions as well as a result of human pressure. With more individuals detected over longer time span, there would be better estimates of group sizes, age structure and density to understand the demographic responses to ecological changes and anthropogenic pressure.

A distinctly smaller female composition was observed in odd groups. With the knowledge of elephants being in frequent fusion and fission societies, this was an interesting observation (Fishlock et al, 2012). This observation occurred simultaneously with the observations of the first order of mother and calf units observed in other populations (Douglas-Hamilton, 1972; Moss and Poole, 1983; Vidya and Sukumar, 2005), but more similarly with the group size observed with the bai forest elephants (Morgan and Lee, 2007; Turkalo, 2013). Whether these groupings have social tiers remains to be tested and monitored over time as there might be a possibility that elephants move in family units to a certain location but break up into pair units when they reach a destination, e.g. mineral licks (Moss et al, 2011). Exhange of members

between groups was suspected, especially those in the ungrouped and individuals that were not associated on the first few detections. However, I was not able to isolate such events based on the obtained footage.

Based on the network graph (fig. 4), five out of the six group clusters showed a combination of family, odd groups, and lone bulls interaction. Interestingly, bulls seemed to show association across different groups of females except for M20 whom was never detected with the presence of other groups. Female loner F4-16, a female adult that had an unclear reproductive status (i.e. breast development was not visible) had visited the lick approximately eight times and had the highest degree of association, implying that she had the most interactions with different individuals. The grouping preference of F4-16 remains unclear, whether she is actually a loner or she belongs to a group. Individuals F44, F45, and S39 were recent identifications and their associations remains unknown and weak. Though they seemed to be interacting with certain groups more often than others during their visits. With the group analysis shown in polygons in figure 4, a concern regarding these clustering groups could be that they do not actually show associations. Because I determined the *elephant events*- the start and end of when elephants were detected - and the *interactions between individuals* - who appears with who - based on the time that they are together. There is a possibility that there were no interactions between groups even if they were detected in the same elephant event. Therefore to a certain extent, the network graph shows grouping based on time instead of purely association. For this study, I did not filter the interactions as it will only be more informative with longer observation.

There are a few potential explanation for female floaters that show unclear affiliation. One of them could be that there was not enough observation to group them appropriately. Despite the fact that they seem to roam more often by themselves even though other family groups were around. Or it could be that they genuinely prefer floating between groups like suggested in de Silva and Wittemyer (2012). Lastly, there could be an effect of elephant translocation carried out in the area for the last three decades (DWNP, pers. comms.). Pinter-Wollman et al (2009) found that elephants that were introduced to a new environment tended to associate randomly with local residential elephants, and also showed higher affiliation rates with other individuals that were translocated into the area. It would be informative if we have the database of information on translocated elephants into the study area for comparison and to study the impacts of translocation on social biology. With the GPS-collared elephants MEME had deployed near the area, only one collared non-translocated young bull—Awang Banun (identified based on local

encounters by the villagers and the collar strap that did not worn off)—was caught on camera at the mineral lick.

Individuals like M18 (H4), S38 (25 Trio) and F27 (H7) were seen to be on their own before they were assigned to a group. It is unclear whether they were not detected by the camera traps prior to the groups' first detection or they were already a part of the group but were not detected in the first encounter with the groups. In the case of S38 Lopez, she was first detected briefly on her own. However, a few days later she was re-detected and seemed to be associate closely with F25 and her offspring. After this incident S38 and F25 were consistently detected together afterwards.

4.3.2 Group Sizes

The consistency in the core group members and odd pairs were evident throughout the study period. The group sizes identified between the seven female groups seemed to show little variation, suggesting some stability in group membership. It is known that group size differs significantly between different elephant species residing in different habitats (de Silva and Wittemyer, 2012). Table 4 is a compilation of the studies that had attempted to quantify elephant group sizes from different areas. It shows a significant difference in terms of rainfall and habitat types that could be used as predictive parameters in determining grouping patterns.

Resource availability is one of the factors determining elephant grouping patterns (Blake, 2004; Moss et al, 2011) as it is costly to maintain large groups as well as balance development and reproductive rates between the numbers (Borries et al, 2008). Despite the high diversity of plants in the tropical rainforest, food can be scarcely distributed (Blake et al, 2009). Dung sampling at the mineral lick showed that most of elephant diet consisted of fibrous vegetation all year round but differed in having medium to large seeds during fruiting seasons, thus indicating that fruits are an important part of their diet (Campos-Arceiz et al, 2008; Kroman-Clausen, 2014, pers. comm.). Thus, the habitat type and the food available may be major deterrents for large groupings as it may lead to competition and conflict (Fernando and Lande 2000).

Unlike the African savannahs ecosystem, elephant communication within the mountainous landscape might not be as straightforward as has been documented in the open savannah. McComb et al (2000) suggested that low-frequency communication would be more prominent in forest elephants as compared to the savannah elephants. Additionally, Garstang et al (1995; 2004) validated that with the

right atmospheric and meteorological properties, bio-acoustic communication can be at its optimal transmission in the early evening. It has been discovered that elephants switch between the use of vocalization (sounds within the hearing capacity of humans) and infrasound (>20Hz) to coordinate over long distances with other herds (Poole et al, 1988; McComb et al, 2003). Most of these studies were carried out either on captive specimens or close up with wild elephants in an open flat plain (Payne et al, 1986; O'Connell-Rodwell et al, 2000; Nair et al, 2009, Wrege et al, 2010). There is still a lack of bio-acoustic studies of Asian elephants in the tropical wilderness and how these transmissions travel through the mountainous terrain like BTFC. Thus, the difficulty in communication in the forest might be an additional factor that deters large aggregation of elephants. The probability of acoustics being bounced off and propagated in all direction might decrease the reliance of using acoustic communication to coordinate between elephant groups in such a habitat. However, it is possiblethat the visiting population receives transmission, judging from the behavioral observations of herds standing silently towards a particular direction before moving off in that direction after several videos of idle movement (Note: no specific quantification for this behaviour).

Similar to the bai study in Central Africa (Turkalo et al, 2013; Fishlock, 2011), elephant groupings outside the mineral licks were not systematically traced. However, several researches have observed elephants moving in larger groups and dispersing into smaller units once they reach a destination (Nyakaana et al, 2001; Moss et al, 2011; Othman, N. unpublished data). This implies that they would fuse when they perceive risk in certain landscapes. One such high-risk landscape could be that of the mineral lick area as it has high human use. Researchers working in the region observed groups on their camera traps placed randomly in the forest and at highway underpasses have different ranges in group sizes. Camera traps placed at viaducts which were built near underpasses for animal crossing found sizes of 5–7 elephants were seen (Tan, C. C., DWNP; Clements, R., Rimba. pers. comm.) whereas in the forest sightings were an average of two individuals at random capture sites (Wong, C., WWF), though precaution must be taken in interpreting such data as the demographic information has been neglected in these figures. Additionally, predator pressure in the tropical rainforests might encourage group formation (Blake, 2004; Moss et al, 2011). Nevertheless it supports my observations of visiting elephants moving in pairs of mother and calf within the mineral lick. They would often visit the lick as family groups but subsequent triggers of videos showed pairs of the mother and her young calf moving around the area or feeding at the lick separately from the usual groupings.

***Table 4**: Findings of elephant group sizes in different habitat with several studies being influenced by poaching episodes and/or human disturbances in the past or present [marked with *]. Information on biome/ habitat were extracted from the source and to WWF's vegetation map. *Note: Terminology of group sizes mentioned below are variable. As many might not detect or include actual family group units, especially for the Forest clearing and Asian elephants, therefore additional information of author's terminology of group sizes are stated. Purpose of this table is to serve as a guidance in the structure which has been established in other species and their respective sites.*

Source	Method	Species	*Female Group Size	Rainfall (mm)	Biome/Habitat
Srinivasaiah et al (2012)*	Direct Obs.	*E. maximus*	6.6 (mean ±2.1 SE; range 3-12)	937	Deciduous-Scrub Woodland
Ashokkumar et al (2010)	Direct Obs.	*E. maximus*	4.3 (mean ± 3.2; range 1-26)	600-2000	Tropical-Subtropical Dry Forest
Ramesh et al (2012)	Direct Obs.	*E. maximus*	4.6 (mean ± 0.16; range 1-22)	1000-2000	Tropical-Subtropical Dry Forest
Vidya & Sukumar (2005)*	DNA	*E. maximus*	8 (median)	2000-3000 (7 sites)	Tropical-Subtropical Dry Forest
de Silva et al (2011a)	Direct Obs.	*E. maximus*	2- 3 (median: female adults only)	1486	Moonsoon forest
Katugaha et al (1999)	Direct Obs.	*E. maximus*	3.9 (all groups [mean]; range 1-21) 7.5 (exc solitares [mean]; range 3-21)	1000	Moonsoon forest
Turkalo et al (2013)	Direct Obs.	*L. cyclotis*	2.7 (all group [mean] ± SD 1.3) 3 (exc solitares [mean] ± 1.2)	1660	Tropical rainforest
Morgan & Lee (2007)	Direct Obs.	*L. cyclotis*	2.2 (all group [mean]) 3.1 (exc solitares)	2363	Coastal shrub mixed
Querouil et al (1999)	Direct Obs.	*L. cyclotis*	3.4 (mean)	>1500	Tropical rainforest- Tree savanna
Moss (2001)	Direct Obs.	*L. africana*	17.4 (mean: range 3-48)	341	Semi-arid savannah
Aleper & Moe (2006)	Direct Obs.	*L. africana*	10 (mean; range 3-22)	635- 889	Subtropical Grassland, Savannas & Scrubland
Foley & Faust (2010)*	Direct Obs.	*L. africana*	18.3 (mean ± SD 3.6; range 6-37)	656	Subtropical Grassland, Savannas & Scrubland
Wittemyer (2001)	Direct Obs.	*L. africana*	9 (median; range 3-36)	360	Subtropical Grassland, Savannas & Scrubland
Gobush et al (2008)*	Direct Obs. + DNA	*L. africana*	2.2 (mean ± SE 0.11; range 2-19)	778	Subtropical Grassland, Savannas & Scrubland
McKnight (2015)	Direct Obs.	*L. africana*	8.9 (mean ± 0.22; range 2-66)	390-450	Semi-arid savannah
Douglas-Hamilton (1972)	Direct Obs.	*L. africana*	9.8 (mean)	380-1270	Semi-arid savannah
This study	Camera Trap	*E. maximus*	6 (median: range 2-10)	2311	Tropical rainforest

4.3.3 Sex Ratio

The sex ratio of male to female adults in this visiting population corroborates the findings by Katugha et al (1999), de Silva (2010), and Ashokkumar et al (2010). Williams et al (2013) found a ratio of one male to 2.65 females in Rajaji National Park, India, which they claim to have the healthiest sex ratio for Asian elephants. The sex ratio in our study, 0.57 male to 1 female, seemed reasonable although it could be a threshold that shows a lack of males in the studied population. The majority of our identified males seemed to be young adults with short, thin tusk; only with few exceptions of older males, M02, M11-17, M16, and M20 having bigger body mass and handsome tube-long tusks. The dense forest structure together with the lack of sexual selection for tusk possession (Chelliyah & Sukumar, 2013) could be the few reasons why our elephants have shorter tusks compared to those in the open plains. In my findings, it is not evident that tusklessness is a common occurrence as most of the males including those that were unidentifiable, possessed tusks (Kurt et al, 1995).

To date, there have been 24 elephant carcasses found by Perhilitan due to various reasons such as poaching, poisoning and roadkill cases between the year 2013 to 2015 (Rozidan Md Yasin, 2016; pers. comm.). Despite the low number of poaching recorded as compared to the African continent, five poaching cases involving MEME's collared elephants has been documented. Our elephant populations have been targeted regardless of their smaller tusks. Three of our male GPS collared elephants on the MEME project have been killed for their tusks and all of them were mostly young adults possessing small tusks. Hence, it is important to know the local population before more killings go unnoticed and unaccounted for. Nevertheless due to the behaviour of males, an underestimation in identified individuals may result in the low numbers of males as they spent less time in front of the camera therefore identification was inconclusive for many male detections. Consequently, it is likely that the estimated number of adult males may be an underestimate of the true visiting population.

As suggested, young males tend to leave their natal family around the age of 10 to 15 years old but continue contact with the female herd for several years until he is fully independent (Poole, 1989; Sukumar, 2003; Chakraborty et al, 2014). This supports my observation of subadult males (M06 and M18) being attached loosely to the H4 group. Initially M06 Macho was seen with H4 frequently but over time he appeared inconsistently with the group, coming earlier before the group arrives and leaving later after they had left. M18 Ba, whom looks different from Macho based on tail shape, associate with the group on

several occasions in the absence of Machom, thus leading me to speculate that they are the same male subadult.

4.4 Use of Mineral Lick

4.4.1 Frequency of Visits

Seasonality in visitation was not prominent as frequent usage was observed throughout the year except for February 2013 which had only two visits of identified elephants and was also one of the drier months in that year (102mm; January and June 2013 had 39.9mm and 61mm precipitation rates only). There was some correlation between lick visitation and rainfall (Matsubayashi et al, 2007), possibly because the minerals have leach out onto the soil surfaceduring the wet season, thereby making the minerals more easily accessible to the animals (Matsubayashi et al, 2006). It also suggests that the consumption of soil or minerals would be to supplement nutrients lacking in diet instead of a buffer for food intake, depending on fruit seasonality. This was found to be contrary as compared to Link et al's (2011, 2012) studies which had a lack of seasonality and fruiting variation. Another factor that could potentially attract elephants to the lick could be the fruit availability in the vicinity of the lick area (Kromann- Clausen, pers. comm.).

Families H1 and H4 can be classified as residents as they have shown regular visits over the year (Wittemyer, 2001). The H1 and H4 female herds had the highest visitation rates with an average duration of 5 to 6 hours on each visit. Interestingly, H7 spent the longest time at the lick with only 11 visits, with the average visit duration of 6.67 hours (± SD 4.14), which was slightly longer than H1of 6.3 hours [± SD 5.4] with 30 visits. This might suggest that groups like H1 and H4 (with 33 detected frequency) can afford to spend less time on their visits because they visit regularly. In contrast, the H7 family might have to maximise their visit by spending more time at the lick on each visit. Whether the high rainfall correlates with higher associations between groups and individuals requires more in depth hypothesis testing. Nevertheless it was interesting to observe that elephants of this study seemed to visit the lick more frequently during the wetter months in contrast to the elephant aggregations observed during drier months by de Silva et al, 2011a. It is also possible that they may be aggregating somewhere else during drier months, suggesting that aggregations can be driven by different ecological factors instead of social preferences alone. The lack of seasonality in visitation could be an indication that they have no reason to partition their time with other animals within the community, because of their body and group size that may essentially be a defensive mechanism in itself (Brightsmith et al, 2004; Link et al, 2011). However, there was one incident where a tiger (*Panthera tigris*

jacksonii) was detected few minutes after a herd of elephants exited the lick area in hurry. Although, no killings have been observed before, the threat may be present.

The social differentiation between the odd groups (<3 individuals) and family units (>6 individuals) with different activity budgets could also be a factor that dictate grouping preferences. Ruckstuhl and Neuhaus (1998) found that sexual segregation occurred in ungulates due to the difference between male and female daily needs, therefore forcing them to have different foraging behaviour (Ruckstuhl, 2007). Thus it is reasonable to hypothesize that since the family group has more offspring of different ages and probably more lactating females, and would thus require more frequent visits to the lick for geophagy. Foraging would be less widespread with the constraints of herding younger offspring, as compared to the odd groups which mainly consists of older subadult offspring. It is possible that the difference in energetic requirements and activity budgets between social groups result in fission between the two groups (Ruckstuhl and Neuhaus, 2005; Hamel and Cote, 2007).

Moreover the activity budget theory was found to satisfy sexual segregation of elephants with dimorphic body masses (Shannon et al, 2008). Females are required to feed more to satisfy their demand in nutrition, making it too costly to maintain a cohesive group dynamic of mixed groups of both sexes, hence the separation between females and males (Shannon et al, 2008). Most detections of male visitation consisted mainly of males passing through the area, sparring with another male, or mixing with the female herds, with two observed occasions of attempted 'chase', by non-musthing bulls to uninterested female adults (pers. oberv.). As males tend to disperse further from their natal range for reproductive opportunities (Archie et al, 2007), the Sira Gajah mineral lick probably could be acting as a social arena for groups and individuals to socialise (Fishlock and Lee, 2012).

4.4.2 Activity pattern

Elephants are cathemeral species—species which are active during both day and night—as observed for forest elephants (van Schaik and Griffiths, 1996). However, the elephants visiting Sira Gajah were more active at night, similar to camera trap studies carried out by Wrege et al (2012) and Gessner et al (2013). The results of this study found that elephant visits began relatively late in the evening and continued on until the next morning. Wrege et al (2010) also found that elephants gradually alter their activities from cathemeral to nocturnal when human activity was detected in close proximity, while Gunn et al (2013) suggests that elephants have clearly adapted to raiding crops after dark when humans are inactive. These were not evident

in this study. However, as images of elephants leaving silently or suddenly were captured just before images of visiting tourists or MEME staffs were documented. No tourists were detected on days when elephants stayed from morning to afternoon. It is possible that the noise of the boat engine may alert elephants when people arrive, causing them to leave the vicinity.

4.4.3 Mineral Consumption

Elephants have poor digestibility for plants that contain high levels of tannins and digestion inhibitors (Houston et al, 2001). Similar to our mineral lick site, water holes in forest bais in Africa are an attraction for many elephants. Metsio Sienne et al (2013) concluded that majority of the waterholes used by elephants had higher concentrations of minerals compared to waterholes which were not used by elephants. This indicates that elephants intentionally seek out hotspots with higher concentrations of sodium and sulphur. Studies involving *Tapirus indicus* at other mineral sites in Malaysia found the sites to have a high sodium content (Simpson, B., pers. comm.).

The disparity between males and females feeding on soil is prominent in this study (Fig. 10), a pattern which is line with Holdo et al (2002)'s finding that female elephants feed on minerals more than males. However, factors for mineral consumption such as detoxification of plant compounds and nutrition supplementation for herbivores are not easily explained (Klaus et al, 1998; Mills and Milewski, 2007; Metsio Sienne et al, 2013). The activity budget theory could aid in the understanding of differences between foraging needs and body mass- in terms of gender-. However it can only explain why there is differences in sex and individuals in geophagic behaviour. Studies that found a correlation between nutritional intake during pregnancy and lactating periods, include humans (Johns and Duquette, 1991; Mahaney et al, 2000; Izugbara, 2009) sambar deer, orangutan, and other forest mammals (Matsubayashi et al, 2006; Matsubayashi et al, 2007; Voigt et al, 2008; Molina et al, 2013; Hon and Shibata, 2013). They found geophagy behaviour to be a natural phenomenon during different times of bodily needs. One notable example of feeding was from the H1 family members subadult S05 Subby. It is evident that she spends most of her visiting time consuming soil compared to other group members. However this observation needs to be studied further in order to distinguish feeding habits between age classes. Mineral content analysis should also be conducted in the future and if the Sira Gajah lick is found to provide vital supplementary nutrients for wildlife, protective measures for the site should be promoted (Stephenson et al, 2011).

4.5 Random Observations

4.5.1 Injuries and Awkward Growth

Injuries were observed on two female elephants (Plate 7.) F08 Lady Boss and F12 Lumpy, both sustained injuries on their trunk over the study period. Unlike snare injuries, these are very deep wounds and it appeared that they were slashed on the top of the trunk. The cause for these injuries remain undetermined. Towards the end of the study, S42 Betty (Plate 8) subadult was observed to have a major physical disability on her left leg that caused it grow outwards, leading to slower movement.

Plate 7: *F08 Lady Boss on the left and F12 Lumpy on the right sustaining cut wounds on their trunk few months after their first detection.*

***Plate 8**: S42 Betty with her disabled front left leg.*

4.5.2 Illegal Activities

With regards to mineral licks being hotspots for poaching activity, we have suffered a total of 7 camera losses at Sira Gajah - of this study and Sira Tersau, which is located approximately 10km away from Sira Gajah. It is thus possible that poachers are using these lick sites and have reasons not to be caught on camera. Apart from the stolen cameras, we also detected one oblivious Agarwood (local term: gaharu) collector (Plate 9). We also found nails on a tree near Sira Tersau (Plate 10), which may have historically been used as a hide platform for hunters to ambush animals at mineral lick. Thus, mineral licks are hotspots for ecological studies in conservation and ecotourism, they are also vulnerable areas for illegal activities.

***Plate 9**: Possble Gaharu collector caught on two of the cameras at Sira Gajah on 20th March 2013 at around 2:36pm.*

***Plate 10:** Multiple nails on tree at Sira Tersau. Historically used as a hunting platform overlooking the mineral lick.*

4.5.3 Dominance or Aggression

Despite the lack of events to distinguish dominance within the female herds, there were incidences of aggression between family members utilizing the mineral lick (F22 Haf-Sca towards an unknown female; event), resting of the head above the other elephant (Plate 11) and kicking with the hind leg (Plate 12). These opportunistic observations were not common but the difference in personality traits was prominent in these elephants (Lee and Moss, 2012; Horback et al, 2013) and hence, can be used for further behavioural studies.

Unlike African elephants studies in Amboselli, our study duration was too short to inform us of any clear matriarchal dominance within the herds, though it is also possible that Asian elephant in fact do not possess such hierarchical ranks as found by de Silva et al (2016). However there may be a possibility for future studies on social leadership in the visiting population by observing the visitation frequency of female adults leading groups into lick areas (McComb et al, 2011; Lee and Moss, 2012). Because family group H4 frequently visited with F20-24 female adult taking the lead into the lick and also being the last to leave, it is possible that this behaviour can be used for future assessment of matriarchs in forest elephants.

Plate 11*: Dominance behaviour displayed by F22 Haf Sca 2 (right) to F10 Pizzarina (left). Pizzarina though looks older with her ear folds and skin features, seems to be shorter compared to Haf Sca2 which looks younger and taller in size.*

Plate 12*: Observations of aggression between group members. Two to three cases of older juveniles were seen kicking a younger sibling, although this was not a common occurrence in this study. Here, an older offspring repeatedly kicked the younger one as it neared the lick. Another incident was when the younger one was leaving with the herd, the older offspring raised its leg and kicked the younger one, obstructing its way and forcing it to change its path. During these events, no signs of help were shown from female adults.*

5. Future Studies

As this is the first study of its kind in a tropical rainforest, there is still much to improve on. Few recommendations include:

1) Age class identification criteria for younger offspring and older adults can be better interpreted with pole or tree marking system for future studies.

2) The analysis of mineral compounds of the licks will help us understand the importance of mineral lick in supplementing elephant diet and ultimately the conservation of hotspots which are confined only to certain areas.

3) The comparison of activity patterns with other sites of high elephant usage would assist in understanding the influence of ecotourism on elephant behaviour.

4) The Sira Gajah site would be suitable for conducting genetic studies to assess the relatedness within the population which can further strengthen our understanding in elephant population structure.

5) Lastly, training in observing captive specimens before or during the study period to familiarize with the movement of an elephant's ears and how the different angles of the face would yield different kind of images of the same individual,. A cross disciplinary collaboration with a computer scientist to develop a system that can assist in video camera trapping methods as well as a software for elephant recognition would help advance forest elephant study techniques.

6. Conclusion

This study has met its objective of observing elephants with indirect methods of cameras trapping at an advantageous location. It is one of the first that has systematically quantified the social structure of Asian elephant residing in forests, thus providing an important platform to study their behavior and population health in response to ecological changes. This study has also proven that mineral licks play an important role in elephant diet, for which is more intricate than we first imagined. The importance of conserving forest elephants is evident as their ecological function has a far-reaching effects for other forest species, either through seed dispersal of fruiting species or altering homogenous landscapes (Haynes, 2011). In order to effectively conserve elephants, we need to understand their social behaviour as it is apparent that they depend on social interactions for long term survival. Therefore, it is a positive mark that the current approach can function as a tool to finally observe wild forest elephants without disrupting their natural behaviour and that their social structure. The building block to population studies can be effectively quantified, an essential step to the long term conservation of wild Asian elephants, especially in this ever changing landscape and conflict-prone era (Leimgruber et al, 2003), as we know too little about their ecological functions to be losing them at such a rate.

As Martin (1978) stated, "ideally an elephant study would follow the life history of a generation of elephant from birth to death, but whereas this is quite feasible in certain animal species, it would involve more than the lifetime of a researcher worker in the case of elephant". In order to conserve the species we too have to be persistent in this lengthy social affair.

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Appendix I- Camera Trap Settings

***Plate 12**: Height of the camera must be 1.5m and above to be at about eye level with elephants. If trees diameter is too small, sticks are used for securing the side of the camera, enforcing it against any curious elephants. A digital camera is then used to ensure the camera is pointing at the desired direction.*

***Table 5:** Essential setting options for this study*

Parameters	**Study Setting**
Mode	Video
Video Length	60sec
Interval	1sec
LED Control	Medium (enclosed areas); High (open areas)
Sensor Level	High
Camera Mode	24 Hours
Time Stamp	On
Set Clock	Date & time of our visit
Video Sound	On

Appendix II- Profiles of Identified Elephants

Herd # 1

eleID	name	age.class
F01-09	Rapunzel	adult
F07	Notetail	adult
F08	Lady Boss	adult
S05	Tinkerbell	subadult
S06	Subby	subadult
f07-anon	F07's off	infant
F01/08-anon	unsure whose off	infant

F01-09 Rapunzel

- tail: Distinctly long and curved on the end
- taller than F08

F07 Notetail

- Tail looks like a music note symbol.

F08 Lady Boss

- Both ear distinctly front folded.
- long tail. tail hair only on inner.
- trunk wound

S05 Tinkerbell

S06 Subby

- Body to tail has a distinct protrude.
- Right ear with hole

Herd # 2

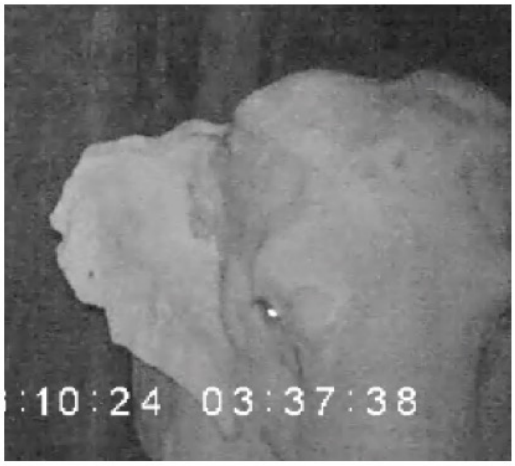
eleID	name	age.class
F10	Pizzarina	adult
F12	Lumpy	adult
F13	Thundress	adult
S37	Whiskerless	subadult
f10-anon	F10's off	infant
f13-anon	unclear	infant

F10 Pizzarina

- Pizza shaped ears. deep front folds.
- Pic with newborn/inf from 8th Nov 2012

F12 Lumpy

- Tumour all over the body.
- Very often uses twigs to swath body

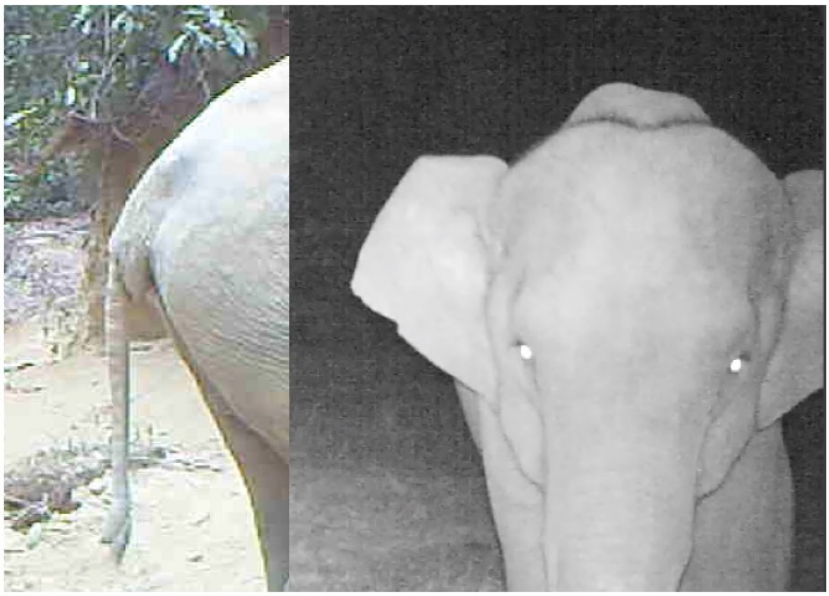


F13 Thundress

- Thunder-like notch on left ear, secondary fold
- Right ear: front folded from top to secondary fold.

S37 Whiskerless

- Scarse hair on tail
- Right ear: crooked
- Didn't see her initially on the first herd detection.



Herd # 3

eleID	name	age.class
F14	Cauliflower	adult
F15	Box Ear	adult
S36	-	subadult
M05	-	male juvenile
f14-anon	f14's offs	newborn/infant
f15-anon	f15's offs	infant

F14 Cauliflower

- top of both ear have distinct curly folds making it look like vegetable flowers.
- deep folds on both ears

F15 Box Ear

- square ears with square lobes.
- slightly rounded after 'third' edge.
- left ear serrated close to 2nd-3rd edge

S36

M05 (male juvenile)

Herd # 4

eleID	name	age.class
F20-24	-	adult
F21	-	adult
F22	Haf Sca 2	adult
M06	Macho	male subadult
f20-anon	F20's off	infant
f22-anon	F22's off	infant

F20-024

- Similar looking right ear to F001-009 but her left ear's fold and edgy curtain defines her.
- young infant.

F21

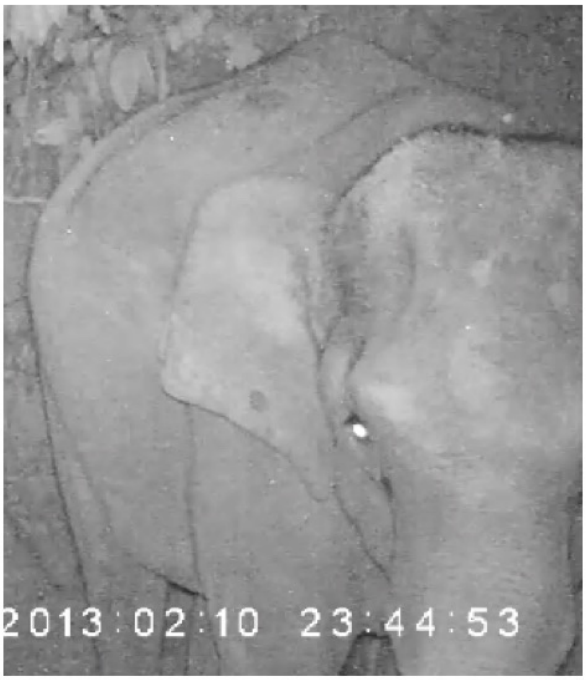
F22 Haf Sca 2

- short tail and no hair.
- left ear with distinct U notch

Herd # 5

eleID	name	age.class
F31	Righty- O	adult
F32	-	adult
f31-anon	unclear	infant
f32-anon	unclear	infant

F31
Righty- O



F32

Herd #6

eleID	name	age.class
F30	Sahara	adult
F34	Left C	adult
F35	Wanda	adult
S41	-	subadult
M22	-	male juvenile
anon		juvenile
anon		infant
anon		infant
anon		infant
f35-anon	F35's off	newborn

F30 Sahara

- large ears, very distinct compared to all the females.

F34 Left C

- Only left ear with big C notch

F35 Wanda

- '弯弯' in chinese pronounced as wan wan, means slanted.
- Both her ears are wonky in shape.

S41

M22

- still young. tusks splayed outwards

Herd #7

eleID	name	age.class
F18-23	Big C	adult
F19	Aly	adult
F27	-	adult
f18-anon	F18's off	juvenile
f19-anon	F19's off	infant

F18-23 Big C

- Somehow has a flamboyant personality. barging in and out of the area like nobody's business.
- distinct C notches on both ear.

F19 Aly

- Left ear: with a u notch creating an extra skin hanging down.
- Front curled both ears

F27

- Vague. but ear veins useful for recapture.

Odd Groups

Group	eleID	age.class
Tailess Duo	F11 Haf Sca M01 Tailess	adult male subadult
Hook T Duo	F29 Hook T M03	adult male subadult
25 Trio	F25 offspring S38 Lopez	adult infant subadult
Short T Duo	F28 Short T offspring	adult infant
Floater	F04-16	adult

Tailess Duo

Hook T Duo

25 Trio

Short T Duo

F04-16
Left Blindy

- Left eye like Wanda has no eye-shine at night.
- always seen with other herds-random

Males

M02 B.O	M11 Right-Notched	M17 Glitch
M04 Pedro	M12	M18 Ba (H4)
M07	M13	M19
M08	M14 Pendek-V	M20 Left Chunkie
M09	M15 Sawtooth	M21
M10	M16 Mike-C	-

M21

- fed a lot on soil
- ear shape round-ish.

*** Due to safety measures, bull profiles were omitted from this document.**

Appendix III- Weighted Matrix Result

	X4.Le.Blindy	X1.Rapunz	X5.Tinker	X6.Sub	X7.Note	X8.La.Boss	X10.Pizzar	X12.Lumpy	X37.Whiskerl	X13.Thundres	X14.Cauliff	F15	M5	S36	F20.24	F21	X22.HafSca2	M6.Macho	M18.Ba	F25	X38.Lopez	X11.HafSca	M1.Talless	X28.ShortT
X4.Le.Blindy	0	0.066666667	0.064516129	0.0625	0.058823529	0.058823529	0.111111111	0.117647059	0.1875	0.142857143	0.0625	0.058823529	0	0.071428571	0.0625	0.095238095	0.066666667	0.1	0	0.157894737	0.047619048	0.047619048	0.047619048	0
X1.Rapunz	0.066666667	0	0.956521739	0.84	0.777777778	0.846153846	0.066666667	0.068965517	0.107142857	0.076923077	0	0	0	0.179487179	0.060606061	0.189189189	0.096774194	0.148148148	0.214285714	0.172413793	0	0	0	0
X5.Tinker	0.064516129	0.956521739	0	0.88	0.814814815	0.814814815	0.1	0.066666667	0.103448276	0.074074074	0	0	0	0.175	0.058823529	0.184210526	0.09375	0.142857143	0.206896552	0.166666667	0	0	0	0
X6.Sub	0.0625	0.84	0.88	0	0.923076923	0.851851852	0.096774194	0.064516129	0.1	0.071428571	0	0	0	0.2	0.088235294	0.210526316	0.125	0.137931034	0.2	0.161290323	0	0	0	0
X7.Note	0.058823529	0.777777778	0.814814815	0.923076923	0	0.925925926	0.090909091	0.060606061	0.09375	0.066666667	0	0	0	0.190476191	0.083333333	0.2	0.117647059	0.129032258	0.1875	0.151515152	0	0	0	0
X8.La.Boss	0.058823529	0.846153846	0.814814815	0.851851852	0.925925926	0	0.058823529	0.060606061	0.09375	0.066666667	0	0	0	0.190476191	0.083333333	0.2	0.117647059	0.129032258	0.1875	0.151515152	0	0	0	0
X10.Pizar	0.111111111	0.066666667	0.1	0.096774194	0.090909091	0.058823529	0	0.727272727	0.461538462	0.6	0	0.058823529	0	0.096774194	0.045454545	0.103448276	0	0.117647059	0	0.1	0.1	0	0.1	0
X12.Lumpy	0.117647059	0.068965517	0.066666667	0.064516129	0.060606061	0.060606061	0.060606061	0.727272727	0	0.636363636	0.666666667	0	0.0625	0.1	0.047619048	0.10714285	0	0.125	0.105263158	0.105263158	0.105263158	0.105263158	0.105263158	0
X37.Whiskerl	0.1875	0.107142857	0.103448276	0.1	0.09375	0.09375	0.461538462	0.636363636	0	0.5	0	0	0	0.137931034	0.047619048	0.148148148	0.05	0.125	0.105263158	0.105263158	0.05	0.05	0	0
X13.Thundres	0.142857143	0.076923077	0.074074074	0.071428571	0.066666667	0.066666667	0.6	0.666666667	0.5	0	0	0	0	0.071428571	0	0.076923077	0	0.153846154	0.125	0.125	0.125	0.125	0.125	0
X14.Cauliff	0.0625	0	0	0	0	0	0	0	0	0	0	0	0.875	0.714285714	0.714285714	0	0	0	0	0	0	0	0	0
F15	0.058823529	0	0	0	0	0	0.058823529	0.0625	0	0	0	0.875	0	0	0.625	0	0	0	0	0	0	0	0	0
M5	0	0	0	0	0	0	0	0	0	0	0.714285714	0	0.625	0.666666667	0	0	0	0	0	0	0	0	0	0
S36	0.071428571	0	0	0	0	0	0	0	0	0	0.714285714	0.625	0.666666667	0	0	0	0	0	0	0	0	0	0	0
F20.24	0.0625	0.179487179	0.175	0.2	0.190476191	0.190476191	0.096774194	0.1	0.137931034	0.071428571	0	0	0	0	0.48	0.916666667	0.44	0.375	0.125	0.161290323	0	0	0	0
F21	0.095238095	0.060606061	0.058823529	0.088235294	0.083333333	0.083333333	0.045454545	0.047619048	0.047619048	0	0	0	0.48	0	0.458333333	0.222222222	0.086956522	0.044736842	0.133333333	0.172413793	0	0	0	0
X22.HafSca2	0.066666667	0.189189189	0.184210526	0.210526316	0.2	0.2	0.103448276	0.107142857	0.148148148	0.076923077	0	0	0	0.916666667	0.458333333	0	0.47826087	0.347826087	0.133333333	0.172413793	0	0	0	0
M6.Macho	0.1	0.096774194	0.09375	0.125	0.117647059	0.117647059	0	0.125	0.05	0	0	0	0	0.44	0.25	0.47826087	0	0	0.043478261	0.090909091	0	0	0	0
M18.Ba	0	0.148148148	0.142857143	0.137931034	0.129032258	0.129032258	0.117647059	0.125	0.125	0.153846154	0	0	0	0.375	0.222222222	0.347826087	0	0	0.166666667	0.166666667	0	0	0	0
F25	0.157894737	0.214285714	0.206896552	0.2	0.1875	0.1875	0.1	0.105263158	0.105263158	0.125	0	0	0	0.125	0.086956522	0.133333333	0.043478261	0.166666667	0	0.714285714	0	0	0	0
X38.Lopez	0.047619048	0.172413793	0.166666667	0.161290323	0.151515152	0.151515152	0.1	0.105263158	0.105263158	0.125	0	0	0	0.161290323	0.041666667	0.172413793	0.090909091	0.166666667	0.714285714	0	0	0	0	0
X11.HafSca	0.047619048	0	0	0	0	0	0.1	0.105263158	0.05	0.125	0	0	0	0	0	0	0	0	0	0	0	0	1	0
M1.Talless	0.047619048	0	0	0	0	0	0.1	0.105263158	0.05	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X28.ShortT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
X29.HookT	0.125	0	0	0	0	0	0	0	0.0625	0	0	0	0	0	0	0	0	0	0	0	0	0.052631579	0.052631579	0.083333333
M3	0.133333333	0	0	0	0	0	0	0	0.066666667	0	0	0	0	0	0	0	0	0	0	0	0	0.055555556	0.055555556	0.090909091
X30.Sahara	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.142857143	0.142857143	0	0	0	0	0	0	0	0	0.142857143
X34.LeftC	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.142857143	0.142857143	0	0	0	0	0	0	0	0	0.142857143
X35.Wanda	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.142857143	0.142857143	0	0	0	0	0	0	0	0	0.142857143
S41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.166666667
X18.BigC	0.25	0.066666667	0.064516129	0.0625	0.058823529	0.058823529	0	0	0.055555556	0	0	0	0	0	0.0625	0.095238095	0.066666667	0.1	0	0.047619048	0	0	0	0
X19.Aly	0.266666667	0.068965517	0.066666667	0.064516129	0.060606061	0.060606061	0	0	0.058823529	0	0	0	0	0	0.064516129	0.1	0.068965517	0.105263158	0	0.105263158	0.05	0	0	0
F27	0.090909091	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.071428571	0.043478261	0.076923077	0	0.076923077	0	0	0	0
F44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.071428571	0.043478261	0.076923077	0	0	0	0	0	0.166666667
F45	0.066666667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.055555556	0	0	0	0	0	0	0	0
S39	0	0.136363636	0.130434783	0.125	0.115384615	0.115384615	0.181818182	0.2	0.2	0.285714286	0	0	0	0.08	0	0.086956522	0	0.2	0.153846154	0.153846154	0	0	0	0
M2.B.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M4.Pedro	0.052631579	0.032258065	0.03125	0.03030303	0.028571429	0.028571429	0	0	0	0	0	0	0	0.133333333	0	0.15	0.103448276	0.157894737	0	0.047619048	0	0.047619048	0.047619048	0
M7	0.09090909	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.071428571	0.043478261	0.076923077	0	0.076923077	0	0	0	0
M11.17.R.Not	0.047619048	0.03030303	0.02941176	0.028571429	0.027027027	0.027027027	0.047619048	0.05	0.05	0.058823529	0	0	0	0	0.058823529	0.086956522	0.0625	0.043478261	0.05	0	0	0	0	0.0625
M12	0	0.032258065	0.03125	0.03030303	0.028571429	0.028571429	0	0	0	0	0	0	0	0	0.0625	0.045454545	0.032258065	0	0.055555556	0.1	0.1	0	0	0
M13	0	0.125	0.12	0.115384615	0.107142857	0.107142857	0.153846154	0.166666667	0.166666667	0.222222222	0	0	0	0	0.115384615	0.058823529	0.125	0	0.272727273	0.214285714	0.214285714	0	0	0
M14.PendekV	0	0.04	0.038461538	0.037037037	0.034482759	0.034482759	0	0.083333333	0.083333333	0	0	0	0	0	0.037037037	0.0625	0.04	0	0.083333333	0.066666667	0.066666667	0	0	0
M15	0	0.125	0.12	0.115384615	0.107142857	0.107142857	0.071428571	0.076923077	0.076923077	0.1	0.090909091	0.083333333	0.111111111	0.111111111	0.074074074	0.058823529	0.08	0	0.166666667	0.133333333	0.133333333	0	0	0
M16.Mike	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M20.Le.Chunk	0	0.037037037	0.074074074	0.071428571	0.066666667	0.032258065	0.066666667	0	0	0	0	0	0	0	0.071428571	0	0.076923077	0	0.153846154	0	0	0	0	0
M21	0.066666667	0	0	0	0	0	0	0	0	0	0	0	0	0	0.034482759	0.117647059	0.037037037	0	0	0	0	0	0	0

	X29.HookT	M3	X30.Sahara	X34.LeftC	X35.Wanda	S41	X18.BigC	X19.Aly	F27	F44	F45	S39	M2.B.O.	M4.Pedro	M7	M11.17.R.Not	M12	M13	M14.PendekV	M15	M16.Mike	M20.Le.Chunk	M21
X4.Le.Blindy	0.125	0.133333333	0	0	0	0	0.25	0.266666667	0.090909091	0	0.066666667	0	0	0.052631579	0.090909091	0.047619048	0	0	0	0	0	0	0.066666667
X1.Rapunz	0	0	0	0	0	0	0.066666667	0.068965517	0	0	0	0.136363636	0	0.032258065	0	0.03030303	0.032258065	0.125	0.04	0.125	0	0.037037037	0
X5.Tinker	0	0	0	0	0	0	0.064516129	0.066666667	0	0	0	0.130434783	0	0.03125	0	0.029411765	0.03125	0.12	0.038461538	0.12	0	0.074074074	0
X6.Sub	0	0	0	0	0	0	0.0625	0.064516129	0	0	0	0.125	0	0.03030303	0	0.028571429	0.03030303	0.115384615	0.037037037	0.115384615	0	0.071428571	0
X7.Note	0	0	0	0	0	0	0.058823529	0.060606061	0	0	0	0.115384615	0	0.028571429	0	0.027027027	0.028571429	0.107142857	0.034482759	0.107142857	0	0.066666667	0
X8.La.Boss	0	0	0	0	0	0	0.058823529	0.060606061	0	0	0	0.115384615	0	0.028571429	0	0.027027027	0.028571429	0.107142857	0.034482759	0.107142857	0	0.032258065	0
X10.Pizzar	0	0	0	0	0	0	0	0	0	0	0	0.181818182	0	0	0	0.047619048	0	0.153846154	0	0.071428571	0	0.066666667	0
X12.Lumpy	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0.05	0	0.166666667	0.083333333	0.076923077	0	0	0
X37.Whiskerl	0.0625	0.066666667	0	0	0	0	0.055555556	0.058823529	0	0	0	0.2	0	0	0	0.05	0	0.166666667	0.083333333	0.076923077	0	0	0
X13.Thundres	0	0	0	0	0	0	0	0	0	0	0	0.285714286	0	0	0	0.058823529	0	0.222222222	0	0.1	0	0	0
X14.Caulif	0	0	0.111111111	0.111111111	0.111111111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.090909091	0	0	0
F15	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.083333333	0	0	0
M5	0	0	0.142857143	0.142857143	0.142857143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.111111111	0	0	0
S36	0	0	0.142857143	0.142857143	0.142857143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.111111111	0	0	0
F20.24	0	0	0	0	0	0	0.0625	0.064516129	0.04	0	0	0.08	0	0.133333333	0.04	0.058823529	0.0625	0.115384615	0.037037037	0.074074074	0	0.071428571	0.034482759
F21	0	0	0	0	0	0	0.095238095	0.1	0.071428571	0	0.055555556	0	0	0.15	0.071428571	0.086956522	0.045454545	0.058823529	0.0625	0.058823529	0	0	0.117647059
X22.HafSca2	0	0	0	0	0	0	0.066666667	0.068965517	0.043478261	0	0	0.086956522	0	0.103448276	0.043478261	0.0625	0.032258065	0.125	0.04	0.08	0	0.076923077	0.037037037
M6.Macho	0	0	0	0	0	0	0.1	0.105263158	0.076923077	0	0	0	0	0.157894737	0.076923077	0.043478261	0	0	0	0	0	0	0
M18.Ba	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0.05	0.055555556	0.272727273	0.083333333	0.166666667	0	0.153846154	0
F25	0	0	0	0	0	0	0.1	0.105263158	0.076923077	0	0	0.153846154	0	0.047619048	0.076923077	0	0.1	0.214285714	0.066666667	0.133333333	0	0	0
X38.Lopez	0	0	0	0	0	0	0.047619048	0.05	0	0	0	0.153846154	0	0	0	0	0.1	0.214285714	0.066666667	0.133333333	0	0	0
X11.HafSca	0.052631579	0.055555556	0	0	0	0	0	0	0	0	0	0	0	0.047619048	0	0	0	0	0	0	0	0	0
M1.Tailess	0.052631579	0.055555556	0	0	0	0	0	0	0	0	0	0	0	0.047619048	0	0	0	0	0	0	0	0	0
X28.ShortT	0.083333333	0.090909091	0.142857143	0.142857143	0.142857143	0.166666667	0	0	0	0.166666667	0	0	0	0	0	0.0625	0	0	0	0	0	0	0
X29.HookT	0	0.875	0.1	0.1	0.1	0.111111111	0.058823529	0.0625	0	0	0.076923077	0	0	0	0	0.111111111	0.125	0	0	0	0	0	0
M3	0.875	0	0.111111111	0.111111111	0.111111111	0.125	0.0625	0.066666667	0	0	0.083333333	0	0	0	0	0.117647059	0.133333333	0	0	0	0	0	0
X30.Sahara	0.1	0.111111111	0	1	1	0.666666667	0	0	0	0	0	0	0	0	0	0.071428571	0	0	0.166666667	0	0	0	0
X34.LeftC	0.1	0.111111111	1	0	1	0.666666667	0	0	0	0	0	0	0	0	0	0.071428571	0	0	0.166666667	0	0	0	0
X35.Wanda	0.1	0.111111111	1	1	0	0.666666667	0	0	0	0	0	0	0	0	0	0.071428571	0	0	0.166666667	0	0	0	0
S41	0.111111111	0.125	0.666666667	0.666666667	0.666666667	0	0	0	0	0	0	0	0	0	0	0.076923077	0	0	0.2	0	0	0	0
X18.BigC	0.058823529	0.0625	0	0	0	0	0	0.9	0.2	0	0.454545455	0	0	0.111111111	0.090909091	0.047619048	0.052631579	0	0.076923077	0	0	0	0.142857143
X19.Aly	0.0625	0.066666667	0	0	0	0	0.9	0	0.1	0	0.5	0	0	0.117647059	0.1	0.05	0.055555556	0	0.083333333	0	0	0	0.153846154
F27	0	0	0	0	0	0	0.2	0.1	0	0	0	0	0	0.090909091	0.333333333	0	0	0	0	0	0	0	0
F44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F45	0.076923077	0.083333333	0	0	0	0	0.454545455	0.5	0	0	0	0	0	0.066666667	0	0.058823529	0.142857143	0	0.111111111	0	0	0	0.090909091
S39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.333333333	0	0.142857143	0	0	0
M2.B.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.066666667	0	0	0	0	0	0	0.111111111
M4.Pedro	0	0	0	0	0	0	0.111111111	0.117647059	0.090909091	0	0.066666667	0	0	0	0.090909091	0.1	0.052631579	0	0	0	0	0	0.066666667
M7	0	0	0	0	0	0	0.090909091	0.1	0.333333333	0	0	0	0	0.090909091	0	0	0	0	0	0	0	0	0
M11.17.R.Not	0.111111111	0.117647059	0.071428571	0.071428571	0.071428571	0.076923077	0.047619048	0.05	0	0	0.058823529	0	0.066666667	0.1	0	0	0	0	0	0	0	0	0
M12	0.125	0.133333333	0	0	0	0	0.052631579	0.055555556	0	0	0.142857143	0	0	0.052631579	0	0	0	0.071428571	0.076923077	0.071428571	0	0	0
M13	0	0	0	0	0	0	0	0	0	0	0	0.333333333	0	0	0	0	0.071428571	0	0.125	0.25	0	0	0
M14.PendekV	0	0	0.166666667	0.166666667	0.166666667	0.2	0.076923077	0.083333333	0	0	0.111111111	0	0	0	0	0	0.076923077	0.125	0	0.125	0	0	0
M15	0	0	0	0	0	0	0	0	0	0	0	0.142857143	0	0	0	0	0.071428571	0.25	0.125	0	0	0	0
M16.Mike	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M20.Le.Chunk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M21	0	0	0	0	0	0	0.142857143	0.153846154	0	0	0.090909091	0	0.111111111	0.066666667	0	0	0	0	0	0	0	0	0